16:13:59 OCA PAD INITIATION - PROJECT HEADER INFORMATION 04/12/88

Active

Project #: D-48-811 Cost share #: Rev #: 0
Center # : T5174-0A0 Center shr #: OCA file #:
Work type : PUB SER
Contract#: CONT DTD 880301 Mod #: Document : CONT
Prime #: Contract entity: GTRC

Subprojects ? : N
Main project #:

Project unit: ARCH COLL Unit code: 02.010.164
Project director(s):
AKRIDGE J M ARCH COLL
JOHN P. CLEAVELAND

Sponsor/division names: GA OFC ENERGY RESOURCES /
Sponsor/division codes: 300 / 037

Award period: 880315 to 880915 (performance) 880915 (reports)

Sponsor amount	New this change	Total to date
Contract value	25,440.16	25,440.16
Funded	25,440.16	25,440.16
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: RESIDENTIAL SLAB ON GRADE INSULATION INVESTIGATION

PROJECT ADMINISTRATION DATA

OCA contact: Brian J. Lindberg 894-4820

Sponsor technical contact	Sponsor issuing office
CHARLES HEALY	PAUL BURKS
(404)656-5176	(404)656-5176
GEORGIA OFFICE OF ENERGY RESOURCES	GEORGIA OFFICE OF ENERGY RESOURCES
270 WASHINGTON STREET, S.W.	270 WASHINGTON STREET, S.W.
ATLANTA, GA 30334	ATLANTA, GA 30334

Security class (U,C,S,TS) : U ONR resident rep. is ACO (Y/N): N
Defense priority rating : N/A N/A supplemental sheet
Equipment title vests with: Sponsor GIT
NONE

Administrative comments -
INITIATION - PART II ARTICLE 4 SPECIFIES THAT PUBLICATIONS WITHOUT PRIOR APP-
ROVAL ARE OKAY, BUT ACKOWLEDGEMENT MUST BE GIVEN OF SPONSOR SUPPORT. 3 COPIES

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Date 7/27/89

Project No. D-48-811 Center No. T5174-0A0

Project Director J. M. Akridge School/Lab Architecture

Sponsor Georgia Office of Energy Resources

Contract/Grant No. Contract dtd. 3/1/88 GTRC XX GIT ___

Prime Contract No. N/A

Title Residential Slab on Grade Insulation Investigation

Effective Completion Date 1/31/89 (Performance) 1/31/89 (Reports)

Closeout Actions Required:

___ None
X Final Invoice or Copy of Last Invoice
___ Final Report of Inventions and/or Subcontracts
___ Government Property Inventory & Related Certificate
___ Classified Material Certificate
___ Release and Assignment
___ Other ___

Includes Subproject No(s). ___

Subproject Under Main Project No. ___

Continues Project No. ___ Continued by Project No. ___

Distribution:

X Project Director
X Administrative Network
X Accounting
X Procurement/GTRI Supply Services
X Research Property Management
_ Research Security Services
X Reports Coordinator (OCA)
X GTRC
X Project File
2 Contract Support Division (OCA)
___ Other ___

Architecture Program
College of Architecture
Georgia Institute of Technology
Atlanta, Georgia 30332-0155

(404) 894-4885

June 15, 1988

John P. Cleaveland
College of Architecture
Georgia Tech
Atlanta, GA 30332

Charles Healy, P.E.
Office of Energy Resources
270 Washington St. S.W.
Suite 615
Atlanta, GA 30334

Charles,

In accordance with the contract detailing the Residential Slab on Grade Insulation Investigation please find attached an interim progress report.

OCA COPY 1

Residential Slab on Grade Insulation Investigation

Interim Progress Report
Building Technology Group
College of Architecture
Georgia Tech

June 15, 1988

Literature Search

The literature search to discover material relative to the insulation of earth contact ground structures is progressing normally. We have cataloged 173 citations that appear to be applicable to the research subject on the basis of a title or abstract.

Acquisition of full text of the citations and review will continue through the term of the project.

An IBM DOS formatted 5-1/4" 360k floppy disk containing the present citations is included with this report. The citations are contained in a free standing database which may be executed by typing 'GRNDREF' from the DOS command line. The database is controlled through a moving bar menu similar to Lotus 123. A choice is selected by placing the reverse video bar over the appropriate keyword and selecting with the [Enter] key or entering the first letter of a keyword.

Thermal Network Model

Due to a change in operating system on the Georgia Tech CDC mainframe computing system and the lack of support for the <u>MIDAS</u> software we have decided to effect the thermal network simulations on a variation of the <u>TNODE</u> thermal network program on local computing resources.

<u>TNODE</u> has been modified extensively over the past quarter to facilitate the following:

1) Hourly clear sky and diffuse incident solar radiation on a surface with any angle of incidence for any location,

2) Hourly ambient air temperatures for any location,

3) A larger number of nodes,

4) A new interface that will allow modification of individual nodal input parameters of conductivity, specific heat, volume, area of interface, node to node separation, and initial temperatures,

5) Node temperature and energy flow recording to an output data file,

6) Saving, retrieval, and annotation of a complete input data file.

Two additional software applications were developed to calculate and format ambient air temperature and incident solar radiation tabular data used as input to the simulation program.

The simulation will allow us to identify and record hourly temperatures and energy flows for any node or set of nodes for any period of time during a calendar year simulation. Output data will be captured in an ASCII text file for import and graphical analysis using a spreadsheet.

The applications are presently being verified against known data sets. Test simulations and variable sensitivity analysis will occur through the month of June. Problem modelling will begin thereafter.

Copies of executable code in their present state are included for your review. The simulation application requires the presence of a numeric coprocessor and the functionality of a Microsoft mouse. We will be happy to schedule a demonstration at your convenience.

Administration

No expenditures except for investigator personal services have been made to date. A copy of the project status and budget as of the end of May is included for your review.

We request permission to shift the monies budgeted for computer fees to a capital outlay category to upgrade one of our present systems to more capable computational platform. We intend to purchase a 20 mhz 80386 system unit with a matching 20 mhz numeric co-processor and 2 mb of 80 ns RAM. All additional components including disk drives and video subsystems required to make a functional platform will come from present inventory. The estimated cost is $4200 with monies beyond this expense in the $5000 category returned to the sponsor.

John P. Cleaveland
Co-Principal Investigator

D-48-811

Final Report

Residential Slab on Grade Insulation Investigation

December 15, 1988

Prepared for:
State of Georgia
Office of Energy Resources
270 Washington St. S.W.
Suite 615
Atlanta, GA 30334

by
John P. Cleaveland
James M Akridge

of the
Georgia Institute of Technology
A Unit of the University System of Georgia

Building Technology Group
College of Architecture
Atlanta, GA 30332

Final Report

Residential Slab on Grade Insulation Investigation

December 15, 1988

Prepared for:
State of Georgia
Office of Energy Resources
270 Washington St. S.W.
Suite 615
Atlanta, GA 30334

by
John P. Cleaveland
James M Akridge

of the
Georgia Institute of Technology
A Unit of the University System of Georgia

Building Technology Group
College of Architecture
Atlanta, GA 30332

Table of Contents

List of Figures

List of Tables

Introduction

Introduction

Use of insulation in association with earth contact structures is a relatively new area of concern that has seen a good deal of attention in the last five years. The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) is presently considering modification of their recommendations relative to its use.

Consumers of residential properties have little information from which to judge the effectiveness of earth contact insulation relative to increased efficiency in other areas. Feedback from the local association of general contractors is generally negative with respect to an insulation requirement due to placement problems and general skepticism about its effectiveness.

The present Georgia energy code requires placement of rigid insulation according to a formula based on the number of degree days experienced by location. Insulation would not be required in most of the southern portion of the state of Georgia under the present standard. The energy efficiency programs, Good Cents and Energy Wise, sponsored by the Georgia Power Company and Atlanta Gas Light Company respectfully, do not require the use of earth contact insulation or award any points when present.

The Office of Energy Resources of the Office of the Governor of the State of Georgia funded the Building Technology Group of the College of Architecture of the Georgia Institute of Technology to investigate the use of insulation relative to typical residential slab on grade construction specific to the environmental and soil conditions common to the state of Georgia.

Initial intentions included theoretical simulations of energy flows isolating slab floor assemblies as well as instrumentation and long term monitoring of an actual slab floor assembly. Budget constraints dictated elimination of the field monitoring in favor of increased use of computer simulation.

Problem

This report describes the results of theoretical simulations using a finite differencing model to isolate energy flow about a foundation-slab on grade assembly typical of residential construction across the state. Annual simulations representing varying levels and placement of insulation were executed for two locations. Atlanta (33.6 N latitude) and Albany (31.5 N latitude) were chosen as being representative of the state in terms of environmental conditions and on the basis of availability of required data.

Foundation-Slab Assembly

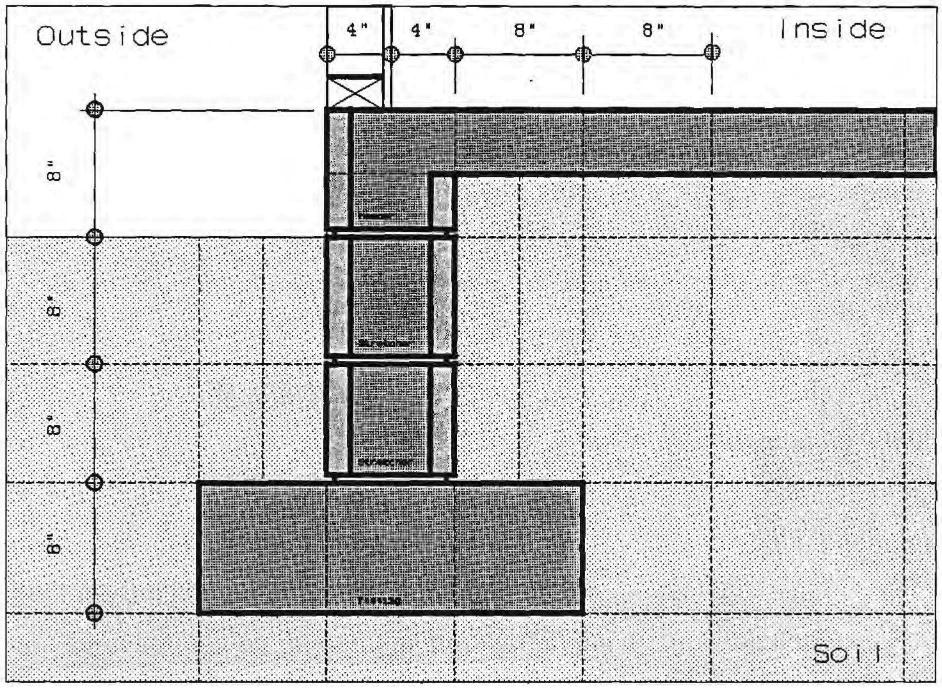
Experience indicates that most residential slab on grade construction typical of this region is monolithic in nature with respect to thermal efficiency. The assembly varies mostly in the nature of the perimeter condition including grade beams, thickened edges, and traditional short foundation walls over separate footings. Variation occurs within a given type mainly by overall dimension, responding to individual loading conditions above and support conditions below. The components are typically concrete placed within formwork with the foundation wall when present ranging to include various concrete masonry unit products.

The placement technique ranges to include a single integral assembly to the more common three-step process involving sequential construction of an individual footing, foundation wall, and slab. When not integral, the components are typically immediately adjacent and are seldom separated by another material creating a boundary condition of material varying only in overall density. Occasionally a small separation is placed between the foundation wall and the slab to accommodate expansion and contraction through the use of a thin control joint material of questionable thermal value.

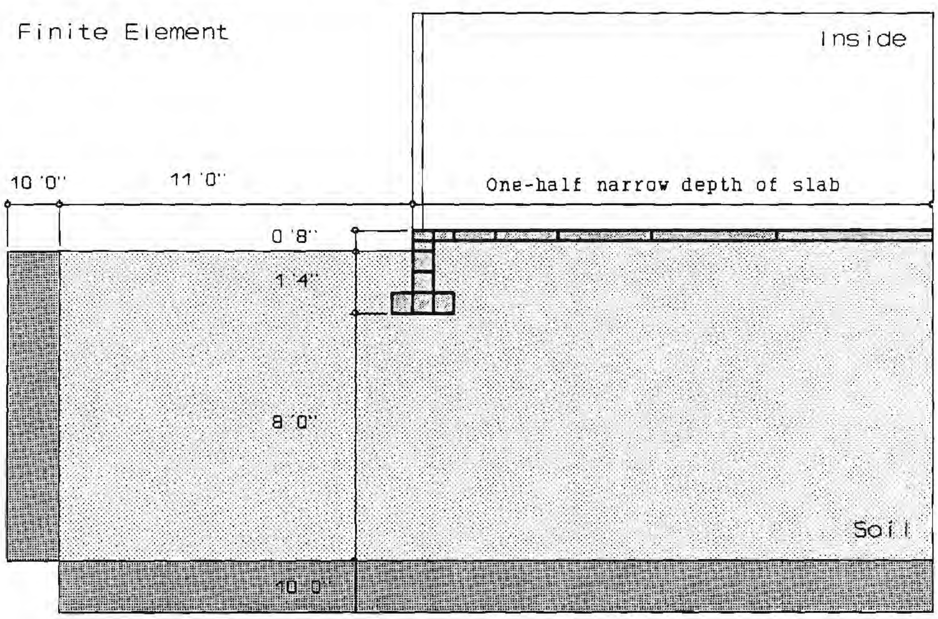
Good construction practice and common sense dictate that the top of any slab assembly exist above exterior grade to effect moisture and insect control. The typical recommendation is a minimum of eight inches above grade with all wood framing and exterior siding terminating at that point. This poses a particular problem in the formation of a thermal bridge of highly conductive concrete to the exterior.

A large percentage of the construction typical of Georgia involves the use of hollow concrete masonry units in a short foundation wall configuration. The section typically is composed of a poured concrete footing placed over undisturbed soil with a short foundation wall of courses of hollow 8" x 8" x 16" (height x depth x width) stretcher concrete masonry units capped with an 8" x 8" x 16" header concrete masonry unit. A concrete slab averaging four inches of thickness is poured atop native soil consolidated via compaction. The concrete of the slab completely fills the cores of the header concrete masonry unit and partially fills the cores of the stretcher concrete masonry units below.

For the purpose of this investigation a basic rectangular plan at a single elevation with four outside corners was assumed. A three component foundation wall assembly was chosen as depicted in Figure 1.1 incorporating concrete masonry units to an overall height of three courses totaling twenty-four inches from top of footing to top of slab. The entire upper course is assumed to exist above exterior grade with all framing and exterior treatment terminating at the top of slab. The cores of all hollow concrete masonry are assumed to become filled with concrete. No control joint or thermal separation exists between the individual components of the slab assembly.



Slab Edge Configuration **Figure 1.1**



Finite Element Model **Figure 1.2**

Finite Element Model

In addition to overall energy movement relative to a unit perimeter width, isolation of directional flows in the earth contact slab assembly were desired by:

1) horizontal distance from the slab edge and
2) vertical distance from the surface of the soil.

In consideration of computational time this dictated that the finite element model consider only a typical two dimensional interior unit width section through the residence and surrounding soil field.

Previous investigations have shown that energy movement in an earth contact slab assembly is largely a function of the influence of the boundary condition at the perimeter. A two dimensional section was taken through the residence from the midpoint of the slab at the narrow width to a position approximately twenty-one feet opposite the foundation wall to a depth of twenty feet.

Assuming a single zone for the model residence and minimizing the effects of orientation, largely a phenomenon of incident solar radiation on the exposed vertical surfaces, the section is representative of all similar sections that are removed from a corner condition by a distance of one-half the width of the slab in the narrow dimension. Moving closer to a corner introduces the influence of a second perimeter condition which should increase flow above the test condition and was beyond the scope of this project.

Procedure

The solution was derived in a two step process. Thermal loads were calculated on a single model residence, excluding floor transfers, using environmental conditions for each of the two target locations. Hourly load profiles were developed from these calculations as input to the finite element simulation that models dynamic flows through an earth contact slab on grade assembly.

A base case of a slab on grade with no insulation was determined for comparison with the residential loads, excluding any floor transfer, and as a reference point for twenty variations of insulation level and placement for each location.

Residential Model

Residential Model

The model residence was defined to be typical of new residential construction common to Georgia. The residence is assumed to be of wood siding over two-by-four stick frame construction pinned to a monolithic concrete slab/foundation wall assembly.

The model residence was assigned the following major attributes:

Conditioned floor area	1800.0 sf
Conditioned volume	14,400.0 cf
Perimeter (33.4 by 53.9 ft)	174.6 ft
Gross exterior wall area	1396.8 sf
Glazed area	240.0 sf
% Floor Area	13.3%
Door area	34.0 sf

Model Gross Attributes **Table 1.1**

The residence was assigned net areas by major cardinal orientation as follows:

Northern and Southern facades:	
Net exterior wall area	344.2 sf ea
Net glazed area	70.0 sf ea
Net door area	17.0 sf ea
Eastern and Western facades:	
Net exterior wall area	217.2 sf ea
Net glazed area	50.0 sf ea

Residence Net Attributes **Table 1.2**

The exterior wall is assumed to be wood siding over one-half inch sheathing applied directly to sixteen inch on center framing from bottom to top plate. Wall cavities occurring between framing are filled with fiberglass insulation batting. The interior is finished with one-half inch gypsum wall board. Assuming standard stick framing technique the wall section has an average composite R-value of 12.00.

The model has a pitched roof with the peak running along the long axis creating an attic space above a flat one-half inch gypsum wall board ceiling at eight feet above finished floor. Insulation is placed to a depth of six inches above the ceiling plane between the sixteen inch on center joists. An average composite R-value of 20.0 is assumed.

Double glazing is assumed consisting of two clear one-eighth inch panes separated by a 3/16 inch air space giving a basic transmission coefficient of 0.56 and an ASHRAE shading coefficient of 0.88. The pitched roof creates an overhang at the southern and northern facades of 1.25 feet deep at 0.5 feet above the head of each five foot high by three foot wide window. The overhang is assumed to extend infinitely left and right of all windows.

Model Load Calculations

Loads for the model residence excluding floor transfers were determined for each of the two target locations using both the CALPAS III[1] and LAODCAL[2] computer simulation programs. The results of the CALPAS III simulation were smoothed and slightly biased toward the LOADCAL results to develop load profiles for a typical day for each month required as input to the finite element model.

The CALPAS III simulation uses proprietary weather data files that are reproductions of National Atmospheric and Oceanographic (NOAA) Typical Meteorological Year (ETMY)[3] data as the basis of external environmental conditions. Full coverage is available for Atlanta, Georgia. A special weather data file was prepared for Georgia Tech by the Berkley Solar Group from a smaller statistical sampling of data (1979-1985) recorded by a local Agricultural Experiment Station near the Albany, Georgia location.

The LOADCAL simulation calculates hourly loads based on the ASHRAE[4] clear sky radiation model and hourly ambient temperatures based on an average monthly temperature and average daily swing. Loads based on solar radiation were linearly reduced by a monthly factor to approximate average conditions.

In addition to the physical definition of the model residence above the following assumptions were made:

Thermostat Setpoints

Heating thermostat	68.0 F
Cooling thermostat	78.0 F

Internal gains (Lighting, Occupancy, Equipment)

Total	16.0 kWh/day

The daily total was distributed on an hourly basis according to the following schedule:

Hour	Distr	Hour	Distr	Hour	Distr
01	.024	09	.056	17	.027
02	.022	10	.060	18	.064
03	.021	11	.059	19	.064
04	.021	12	.046	20	.052
05	.021	13	.045	21	.050
06	.026	14	.030	22	.055
07	.038	15	.028	23	.044
08	.059	16	.031	24	.027

Internal Gain Distribution **Table 2.1**

Infiltration

Base	0.4 ACH
Change	0.015 ACH/F

Base condition of 0.4 air changes per hour (ACH) plus 0.015 ACH per degree Fahrenheit of difference between outside and inside dry bulb temperatures. For Atlanta, GA the 97.5 percentile design conditions established by ASHRAE are 22 F for winter and 92 F for summer. Using the established 68

F and 78 F thermostat setpoints the infiltration rate could reach 1.09 ACH and 0.61 ACH for winter and summer, respectively.

Ground Reflectivity

Average	0.20

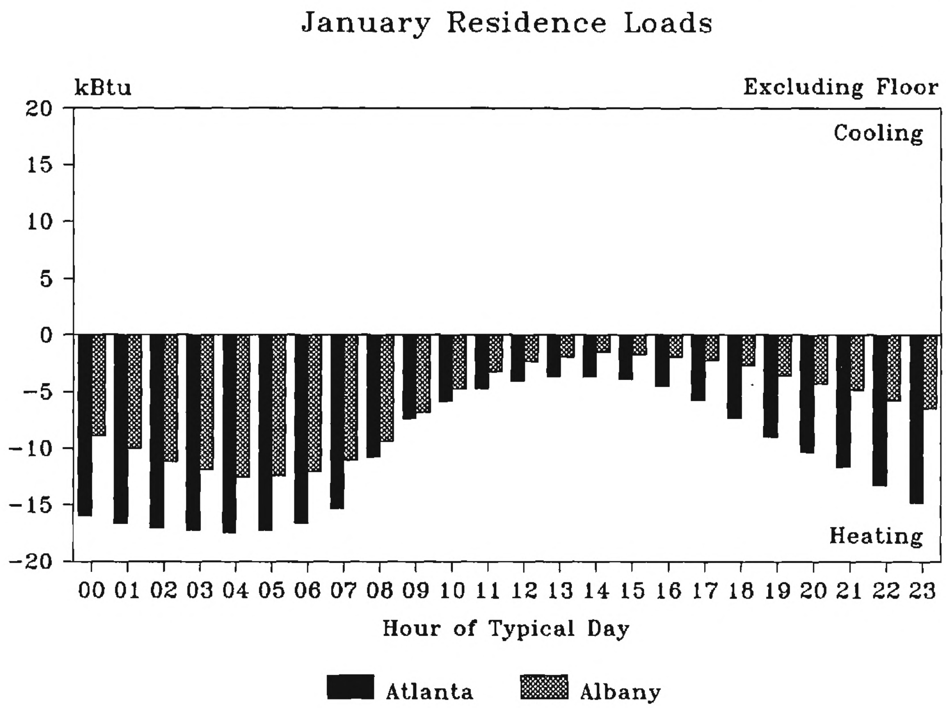
The residence is assumed to be in the clear unshaded by any adjacent structures or natural features. The surrounding surfaces are assumed to be horizontal with average reflectivity of 0.20.

Interior Shading

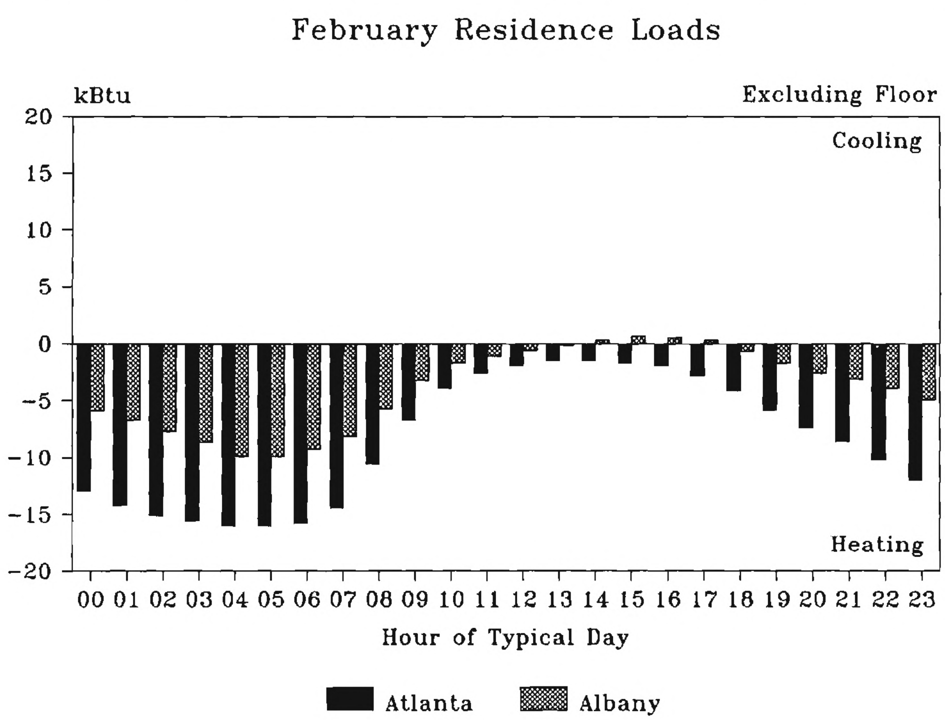
Transmissivity	0.60
Coverage	0.60 winter
	0.70 summer

Interior shading is assumed in the form of draperies that are not completely opaque transmitting 60% of incident radiation. The shading is assumed to average covering 60% and 70% of the glazed area in the winter and summer, respectively.

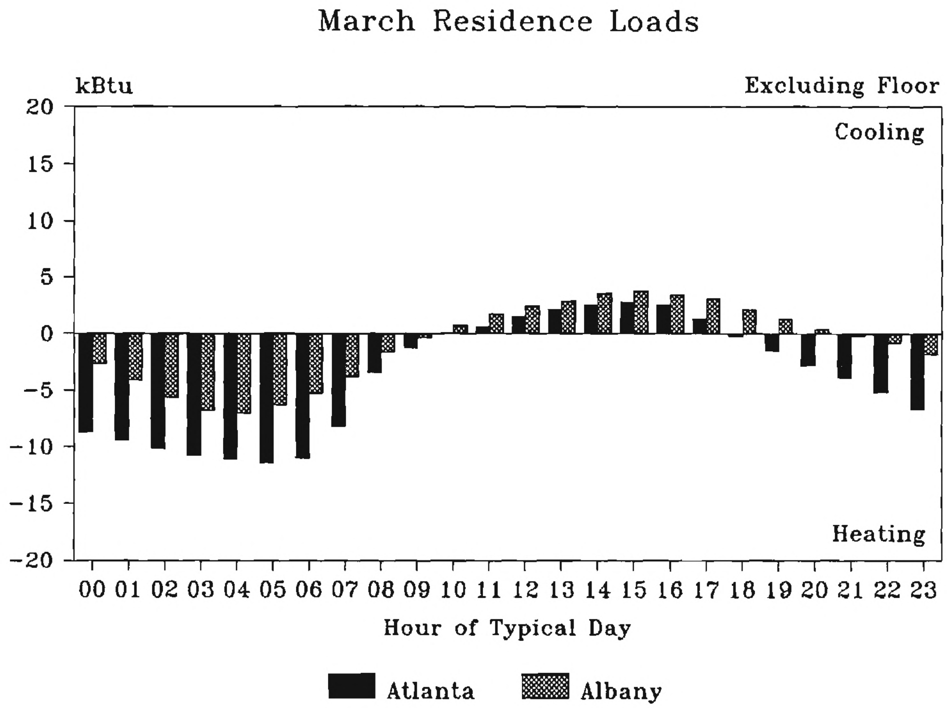
The adjusted simulations produced the load conditions, excluding the effect of any floor transfers, depicted in Figure 1.3. The hourly load profiles derived as input to the finite element analysis are indicated graphically for each location for all months in Figures 2.1 through 2.12.



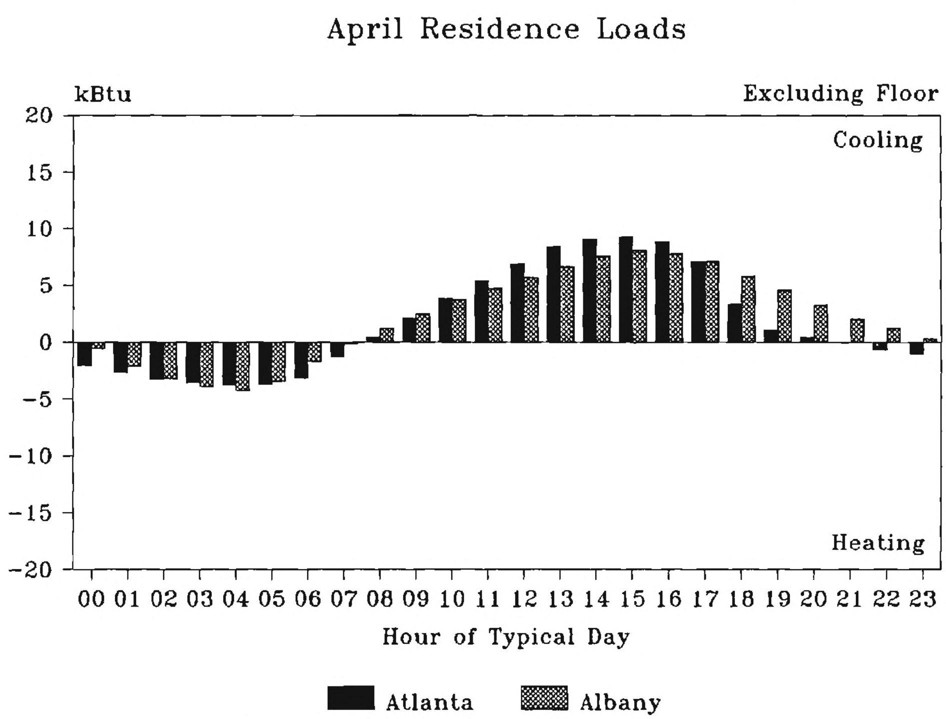
January Residence Loads **Figure 1.3**



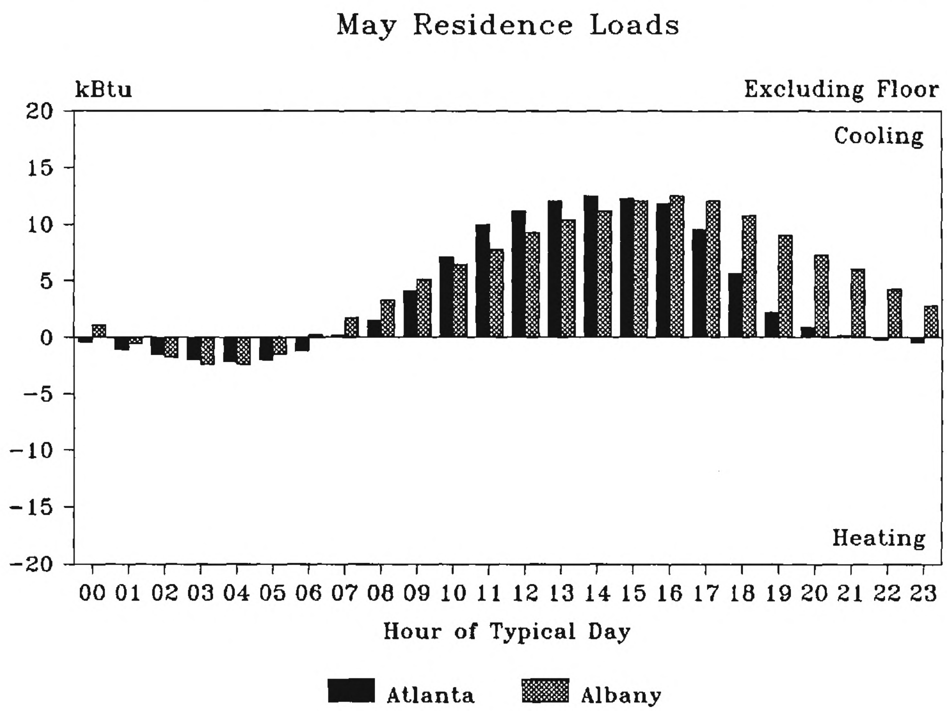
February Residence Loads **Figure 1.4**



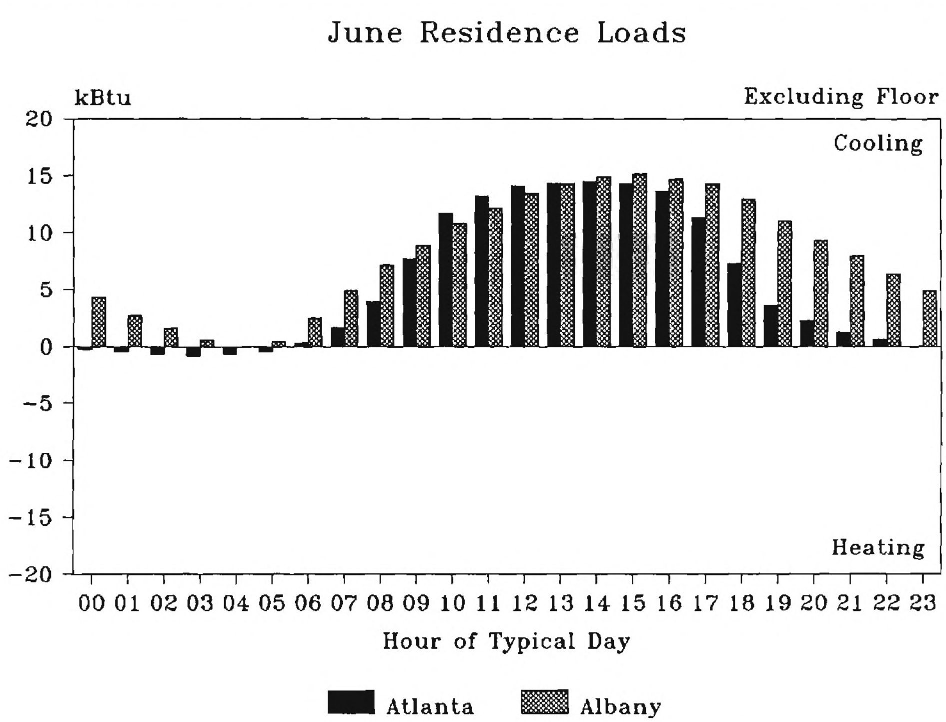
March Residence Loads **Figure 1.5**



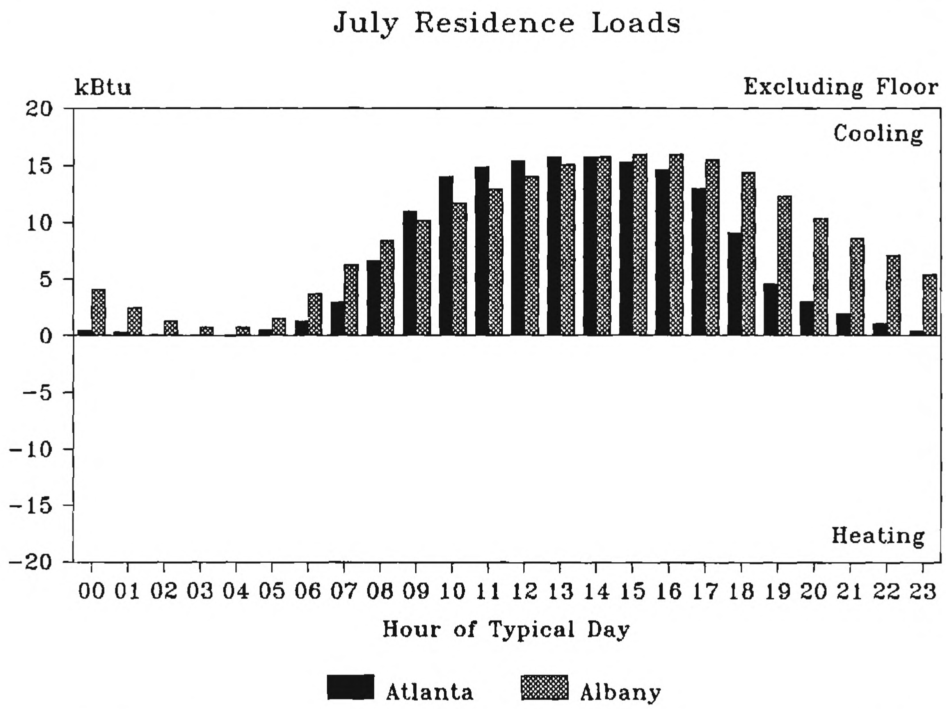
April Residence Loads **Figure 1.6**



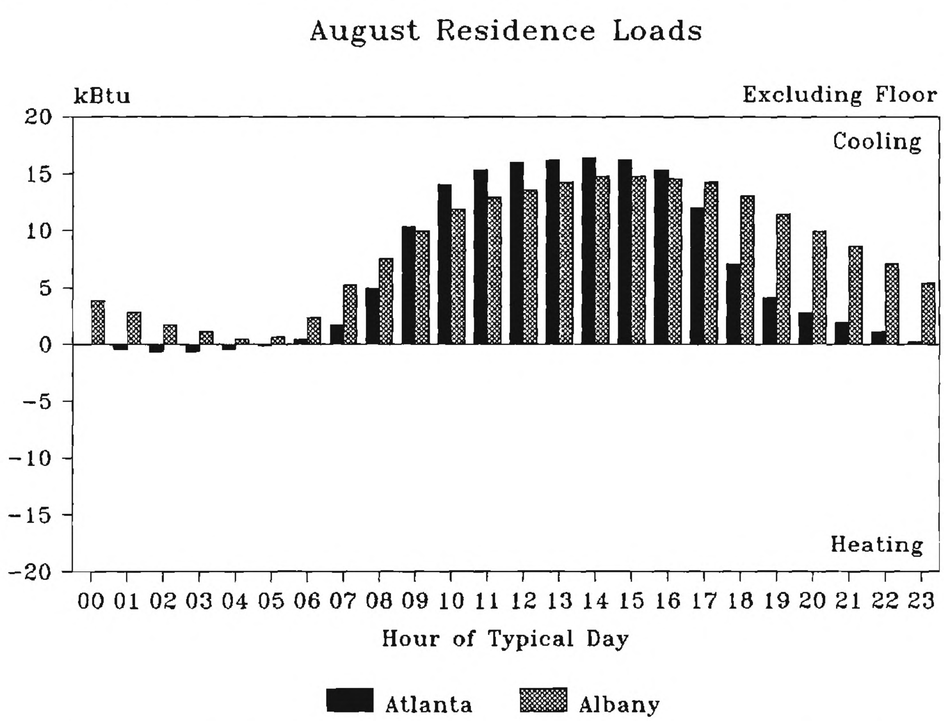
May Residence Loads **Figure 1.7**



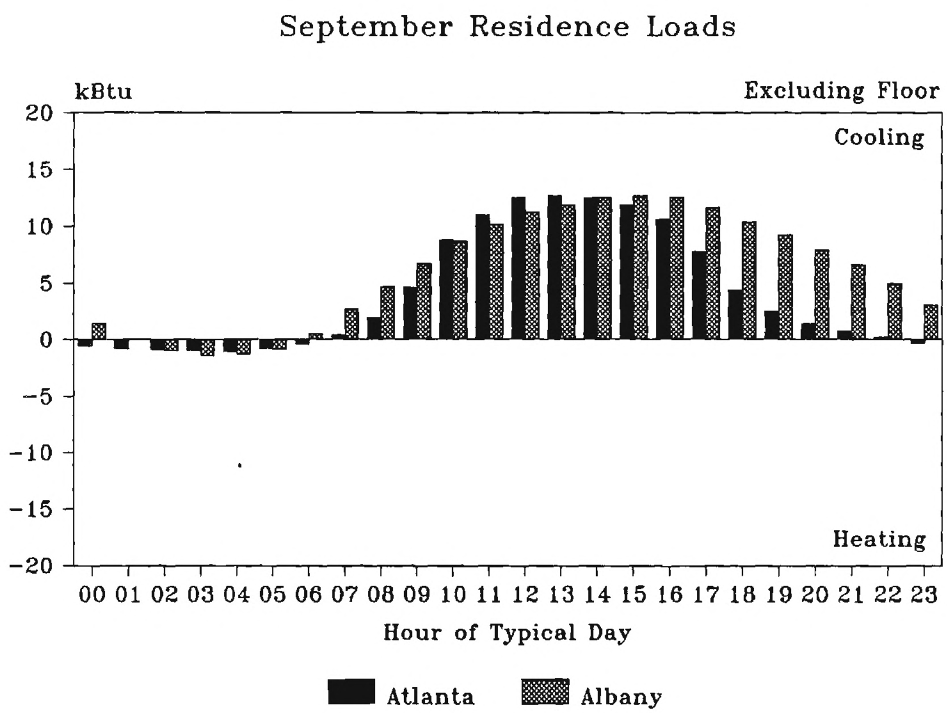
June Residence Loads **Figure 1.8**



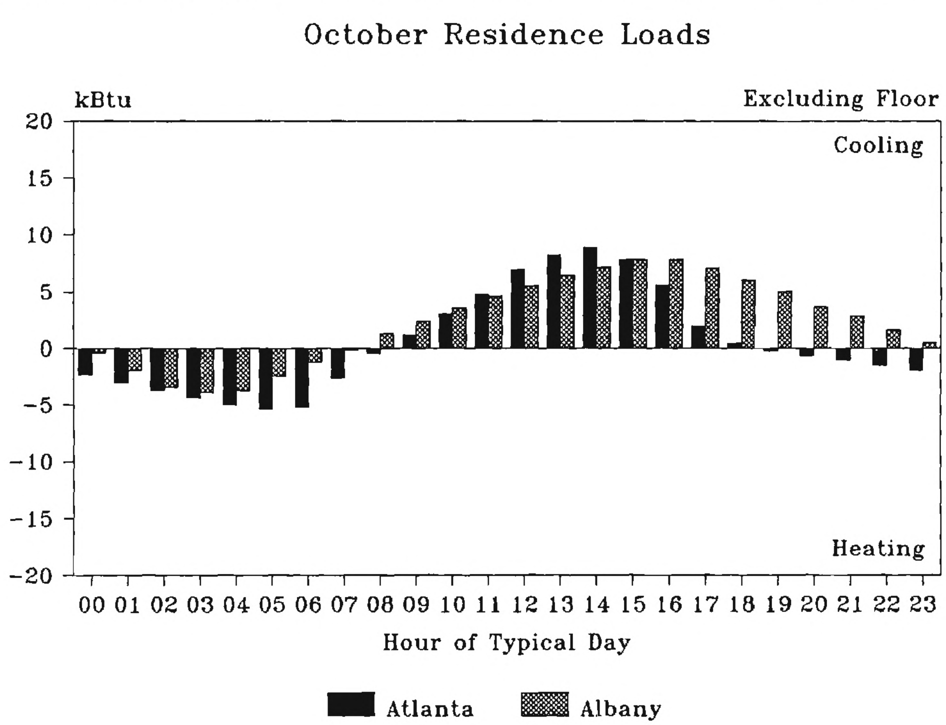
July Residence Loads **Figure 1.9**



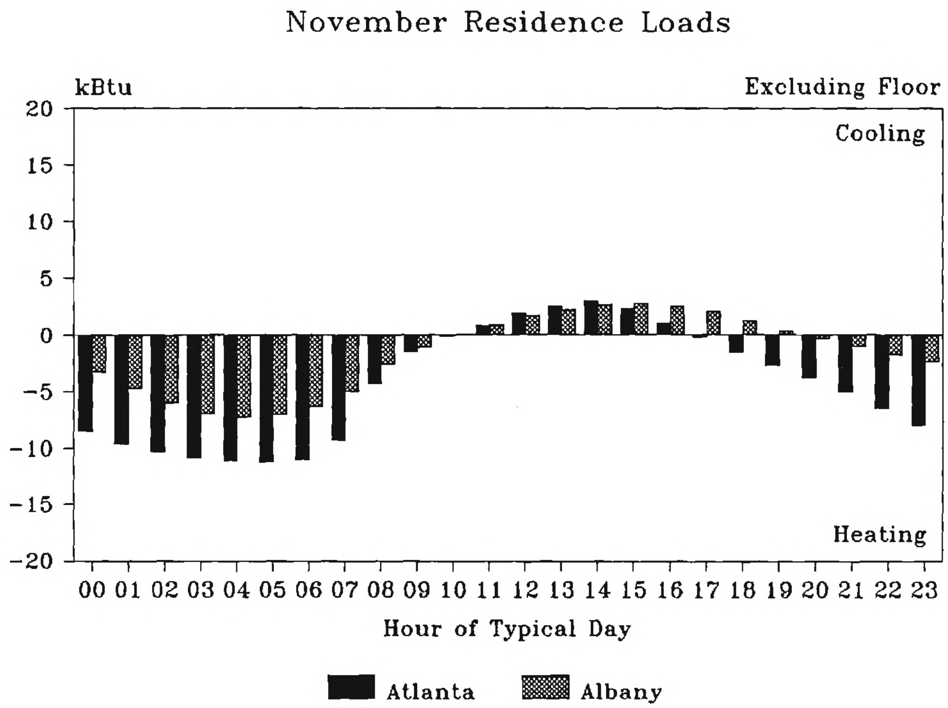
August Residence Loads **Figure 1.10**



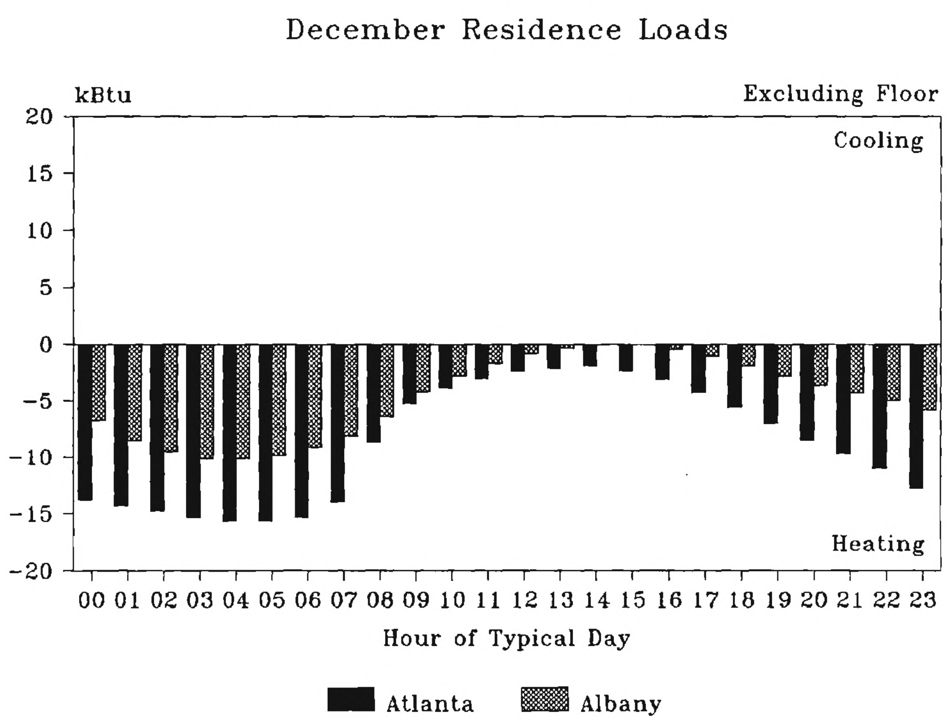
September Residence Loads **Figure 1.11**



October Residence Loads **Figure 1.12**



November Residence Loads **Figure 1.13**



December Residence Loads **Figure 1.14**

Soil

Soil Conditions

Undisturbed ground temperatures are required for each location to establish initial temperatures and ground node thermostats or sinks at the bottom and side of the slab model. Estimation of temperatures by most procedures assumes that:

1) the soil is homogeneous,
2) thermal and physical properties are constant over time,
3) there is no freeze/thaw occurrence,
4) geothermal flow is insignificant, and
5) conduction is the dominant heat transfer mechanism.

Theoretical estimations generally reveal that the temperature of the soil varies sinusoidally at all depths over the period of a year. The amplitude decreases exponentially with increasing depth.

Ground temperature distribution was calculated using the ground temperature method developed by Ken Labs[5]. The method is based on three annual parameters:

1) an average mean temperature,
2) an average amplitude about mean, and
3) a phase constant expressed in the number of days from the beginning of the year at which the temperature wave is shifted producing minimum soil surface temperatures.

Soil parameters depicted in Table 2.2 were assumed for the target locations:

	Atlanta	Albany
Average Mean Temp	60.5	68.0
Average Amplitude	21.0	14.0
Phase Constant	35	27

Soil Parameters **Table 2.2**

Soil properties shown in Table 2.3 were assumed for the target locations:

	Atlanta	Albany
Type	Clay Silt	Sandy Loam
Moisture content	10.0%	10.0%
Specific Heat	0.23	0.23
Density	110.0	110.0
Conductivity	0.750	0.833
Diffusivity	0.71	0.79

Soil Properties **Table 2.3**

The method predicted the temperature profiles shown in Tables 2.4 and 2.5 for the Georgia locations:

Atlanta, GA

Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	40.7	39.9	44.6	53.6	64.4	74.2	80.3	81.1	76.4	67.4	56.6	46.8
1	43.5	41.7	45.6	52.4	62.0	71.1	77.5	79.3	76.0	68.6	59.0	49.9
2	46.2	43.7	45.6	51.6	60.0	68.5	74.8	77.3	75.4	69.4	61.0	52.5
3	48.6	45.6	46.5	51.2	58.4	66.1	72.4	75.4	74.5	69.8	62.6	54.9
4	50.8	47.4	47.5	51.0	57.1	64.1	70.2	73.6	73.5	70.0	63.9	56.9
5	52.8	49.2	48.6	51.1	56.2	62.5	68.2	71.8	72.4	69.9	64.8	58.5
6	54.6	50.8	49.7	51.4	55.6	61.1	66.4	70.2	71.3	69.6	65.4	59.9
7	56.1	52.4	50.8	51.8	55.2	60.0	64.9	68.6	70.2	69.2	65.8	61.0
8	57.4	53.8	51.9	52.4	55.0	59.1	63.6	67.2	69.1	68.6	66.0	61.9
9	58.6	55.1	53.0	52.9	54.9	58.4	62.4	65.9	68.0	68.1	66.1	62.6
10	59.5	56.2	54.0	53.6	55.0	57.9	61.5	64.8	67.0	67.4	66.0	63.1
11	60.3	57.2	55.0	54.2	55.2	57.5	60.7	63.8	66.0	66.8	65.8	63.5
12	60.9	58.1	55.9	54.9	55.4	57.3	60.1	62.9	65.1	66.1	65.6	63.7
13	61.4	58.9	56.7	55.6	55.8	57.2	59.6	62.2	64.3	65.4	65.2	63.8
14	61.8	59.5	57.4	56.2	56.1	57.2	59.2	61.5	63.6	64.8	64.9	63.8
15	62.1	60.0	58.1	56.8	56.5	57.3	58.9	61.0	62.9	64.2	64.5	63.7
16	62.3	60.5	58.7	57.4	56.9	57.4	58.7	60.5	62.3	63.6	64.1	63.6
17	62.4	60.8	59.2	57.9	57.3	57.6	58.6	60.2	61.8	63.1	63.7	63.4
18	62.4	61.1	59.6	58.4	57.7	57.7	58.6	59.9	61.4	62.6	63.3	63.3
19	62.4	61.3	60.0	58.8	58.0	58.0	58.6	59.7	61.0	62.2	63.0	63.0

Undisturbed Soil Temperatures **Table 2.4**

Albany, GA

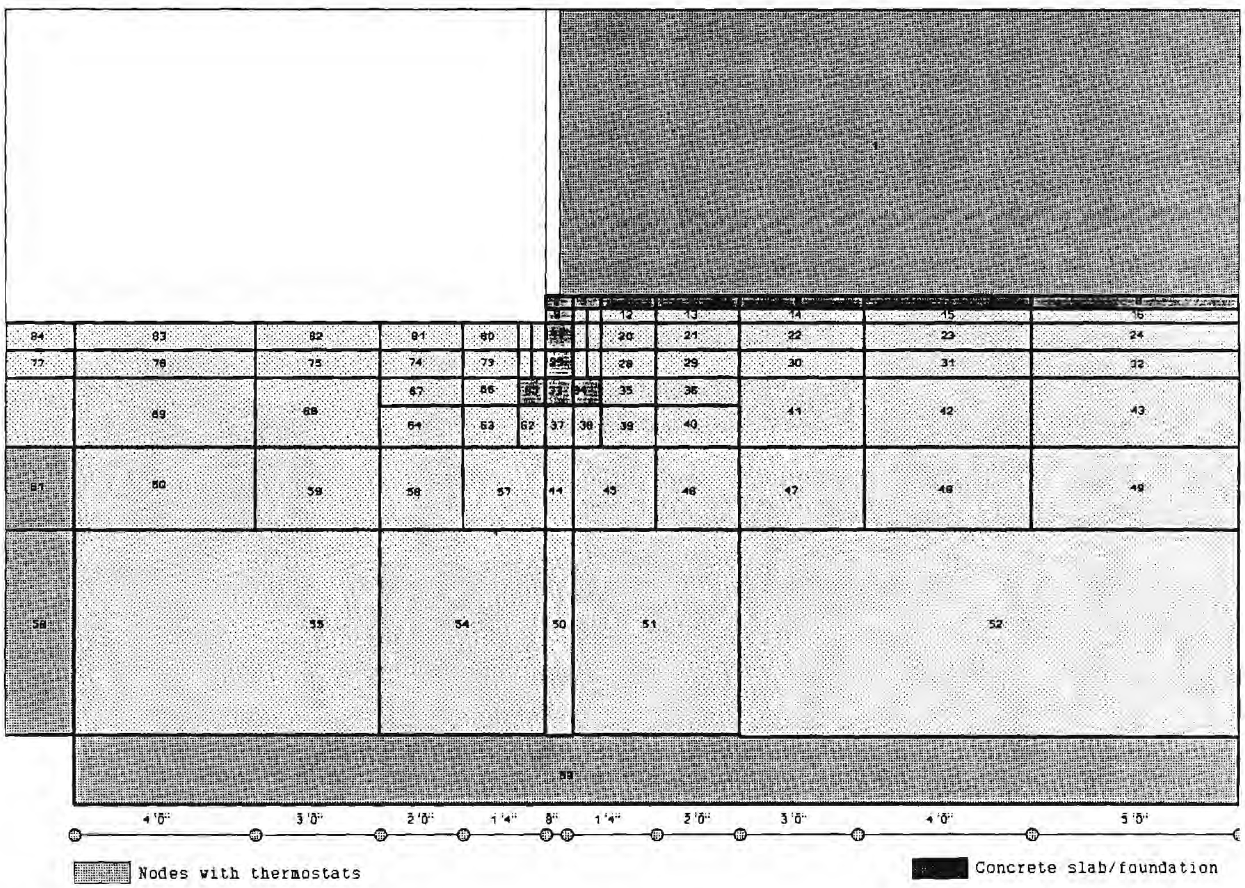
Depth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	54.3	54.7	58.7	65.2	72.5	78.5	81.7	81.3	77.3	70.8	63.5	57.5
1	56.0	55.7	58.7	64.2	70.8	76.5	80.0	80.3	77.3	71.8	65.2	59.5
2	57.6	56.7	58.9	63.5	69.3	74.8	78.4	79.3	77.1	72.5	66.7	61.2
3	59.1	57.8	59.2	63.0	68.1	73.2	76.9	78.2	76.8	73.0	67.9	62.8
4	60.5	58.8	59.6	62.7	67.2	71.9	75.5	77.2	76.4	73.3	68.8	64.1
5	61.7	59.8	60.1	62.5	66.4	70.7	74.3	76.2	75.9	73.5	69.6	65.3
6	62.9	60.8	60.7	62.5	65.8	69.7	73.1	75.2	75.3	73.5	70.2	66.3
7	63.9	61.8	61.3	62.6	65.4	68.8	72.1	74.2	74.7	73.4	70.6	67.2
8	64.9	62.7	61.9	62.8	65.1	68.1	71.1	73.3	74.1	73.2	70.9	67.9
9	65.7	63.5	62.5	63.0	64.9	67.5	70.3	72.5	73.5	73.0	71.1	68.5
10	66.4	64.3	63.2	63.3	64.8	67.1	69.6	71.7	72.8	72.7	71.2	58.9
11	67.0	65.0	63.7	63.7	64.8	66.7	69.0	71.0	72.3	72.3	71.2	69.3
12	67.5	65.6	64.3	64.0	64.8	66.5	68.5	70.4	71.7	72.0	71.2	69.5
13	67.9	66.1	64.8	64.4	64.9	66.3	68.1	69.9	71.2	71.6	71.1	69.7
14	68.3	66.6	65.3	64.8	65.1	66.2	67.7	69.4	70.7	71.2	70.9	69.8
15	68.5	67.0	65.8	65.1	65.2	66.1	67.5	69.0	70.2	70.9	70.8	69.9
16	68.7	67.4	66.2	65.5	65.4	66.1	67.3	68.6	69.8	70.5	70.6	69.9
17	68.9	67.7	66.6	65.8	65.6	66.1	67.1	68.3	69.4	70.2	70.4	69.9
18	69.0	67.9	66.9	66.1	65.9	66.2	67.0	68.1	69.1	69.9	70.1	69.8
19	69.1	68.1	67.2	66.7	66.1	66.3	66.9	67.9	68.8	69.6	69.9	69.7

Undisturbed Soil Temperatures **Table 2.5**

Finite Element Model

Finite Element Model

The analysis section was subdivided into eight-four nodes as depicted in Figure 3.1. Each individual node represents a mass of one type. Attributes of conductivity, density, and specific heat are assigned to each node and inter-nodal relationships are defined by the distance between centroids and area of interface between adjacent nodes. Conductance between adjacent nodes and capacitance of individual nodes are calculated as the basic tools of the thermal network.



Simulation Model **Figure 3.1**

Thermostat were established for four nodes (1, 53, 56, 61) on the basis of a twenty-four hour schedule typical for each month. Temperatures of the nodes were reset to the scheduled values at the end of each hourly calculation iteration after the node temperature swings due to calculated influence. Auxiliary energy required to reset the node temperature is reported for each iteration.

Node one, representing the inside air mass of the model residence was regulated by two thermostats, the same as those used to determine the above slab thermal schedules; a 68 F heating setpoint and a simultaneous 78 F cooling setpoint. Inside temperatures of the air mass was allowed to swing between the two setpoints for the entire annual simulation.

Node fifty-three, the deepest vertical node in the soil field received a schedule of thermostat heating setpoint determined from undisturbed ground temperatures. The node functions as a sink representing a larger mass of soil beneath the defined model. In a similar fashion nodes fifty-six and sixty receive a schedule of thermostat setpoints typical of undisturbed soil temperatures to represent a larger mass of soil at the side of the model.

The effect of solar radiation was considered for all exterior nodes in the soil field and exposed foundation wall. The surface nodes of the soil field were assumed to be horizontal and absorb thirty percent of incident radiation. The two nodes describing the exposed upper eight inches of the foundation wall are assumed to be vertical with an absorptivity of 0.75 when exposed and 0.15 when exterior insulation is in place. The surfaces were assumed to face north to minimize the effect of orientation but not completely negate the role of incident solar radiation.

Conductive coefficients with radiative components were assumed to describe the transfer of energy from ambient conditions to the soil field surface nodes and from the inside air mass to the surface of the slab. In both cases the lesser of the appropriate values recommended in the ASHRAE Cooling and Heating Load Calculation[6] manual were assumed; 4.0 for exterior conditions and 1.08 for interior conditions.

Insulation materials were assigned properties of closed cell extruded rigid insulation as typical of Styrofoam brand type SM as manufactured by Dow Chemical, U.S.A.[7] Their 1987 product specification recommends the five year aged design values given in Table 3.1:

The air node capacitance was calculated using the basic properties of air, the contribution

Conductivity (Btu-in/hr-sf-F)	0.20
Density (lb/cf)	2.216
Specific heat (Btu/lb-F)	0.29

Insulation Properties **Table 3.1**

of all building components inside the interior face of framing, and building furnishings at four Btu/sf-F. The simulation was intended to step four times per hour to model the operation of a mechanical system once every fifteen minutes to maintain thermostat setpoints. In the interest of computational time, the step was increased to once per hour with the air node capacitance increased linearly as an accommodation. Sensitivity simulations of the base case with both prove an increase of the air node capacitance by approximately 100% with a single step per hour effectively models the four time steps per hour situation. Above slab thermal loads are represented as an hourly schedule of internal gains associated with the inside air node.

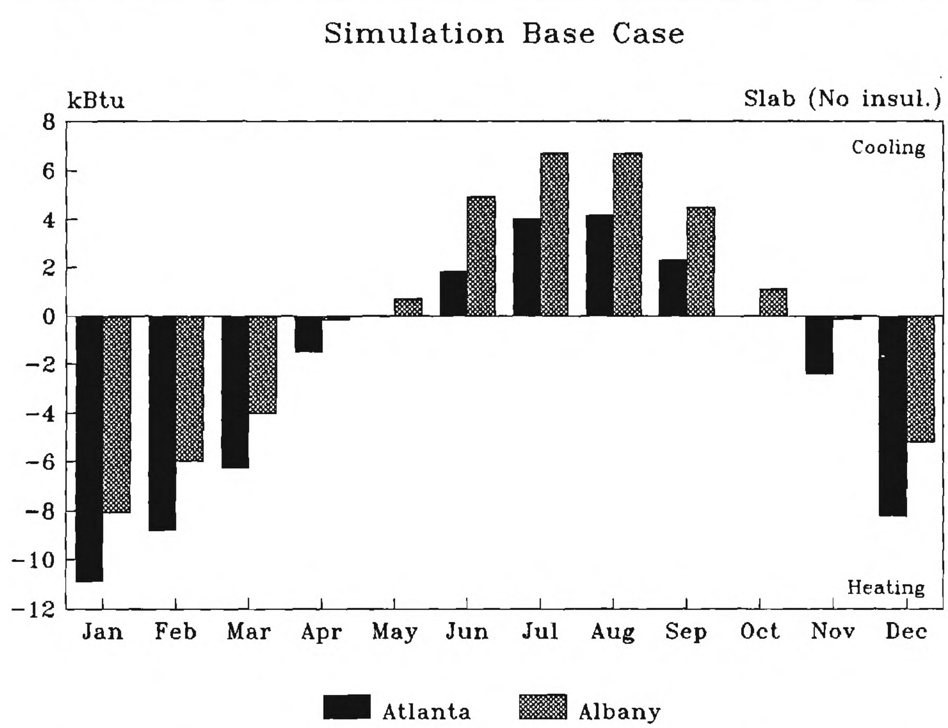
A typical set of input data for the Atlanta, Georgia base case is included in Appendix B.

Base Case

A comparison of the loads for the model residence, excluding floor transfers, with those of the finite element simulation base case of a slab with no insulation is shown in Table 4.1.

	Season	With Slab	Without Slab	Percent Change
Atlanta	Heating	39,526. kBtu	24,836. kBtu	59.1 increase
	Cooling	12,248. kBtu	21,103. kBtu	42.0 decrease
	Total	51,774. kBtu	45,939. kBtu	12.7 increase
Albany	Heating	23,491. kBtu	12,697. kBtu	85.0 increase
	Cooling	24,688. kBtu	30,331. kBtu	18.6 decrease
	Total	48,179. kBtu	43,028. kBtu	12.0 increase

The addition of floor transfers through an uninsulated earth contact slab assembly increases the annual loads by approximately twelve percent for both locations. The seasonal loads,

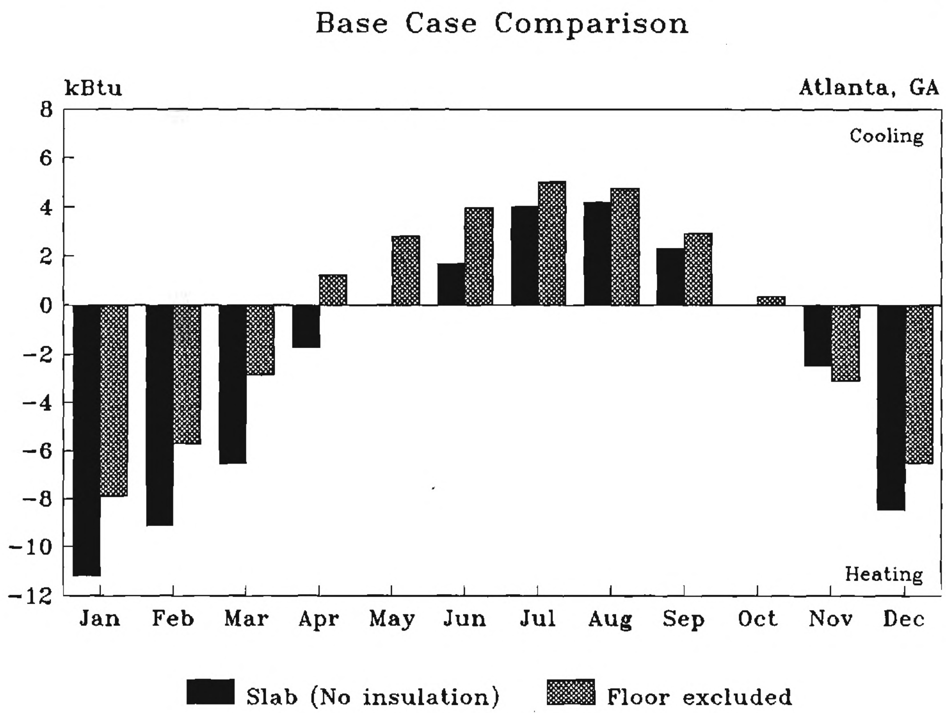


Residence Loads (Slab no Insulation) **Figure 4.1**

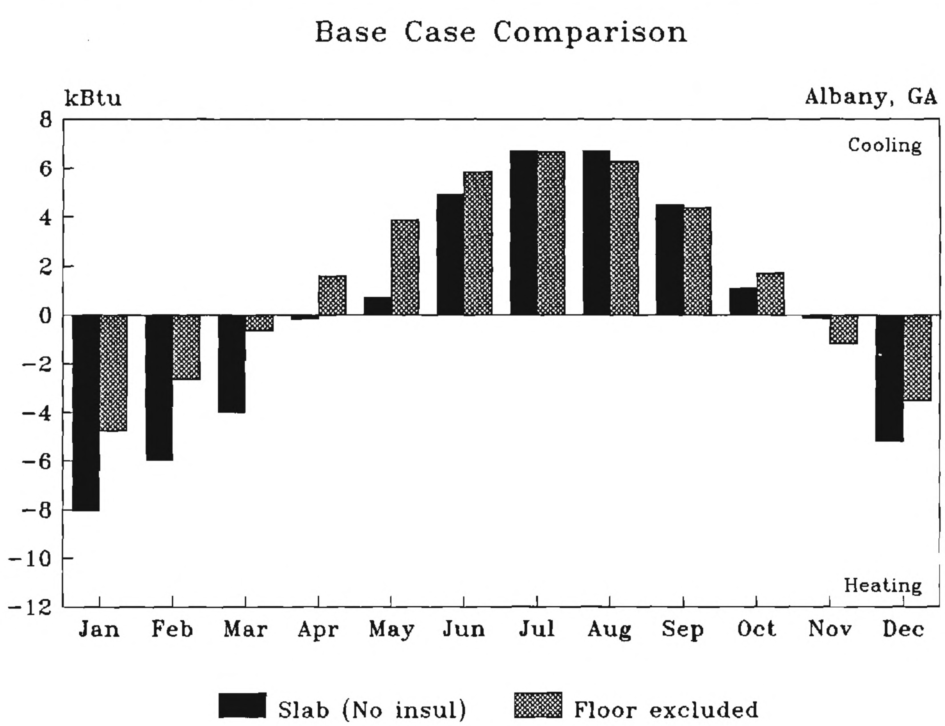
however, show a much more drastic shift with the slab assembly substantially increasing the heating loads and decreasing the cooling loads.

Figure 4.1 indicates the monthly load conditions for the model residence with floor transfers for an uninsulated slab on grade. Figure 4.2 shows a monthly comparison for the Atlanta location. Except for November all months that were previously a heating load showed a substantial increase. April shifted from a slight cooling to a slight heating load. All months that were previously cooling showed some decrease with the small cooling loads in May and October completely eliminated.

A similar comparison for Albany is shown in Figure 4.3. Again all months except November that were previously heating showed a substantial increase. April also shifts from a slight cooling to a heating load. Three months that were previously cooling show a slight increase and three show a decrease.



Atlanta Base Case Comparison **Figure 4.2**



Albany Base Case Comparison **Figure 4.3**

Energy movement was isolated for the base cases for each location and is depicted as figures 4.4 through 4.19. Similar figures for each location are grouped in pairs on a single page. Figures 4.4 and 4.5 depict the movement of energy from the interior air node to the slab on grade and the reverse condition. Both locations have bidirectional flows during a single month for several months during the year. Both locations indicate significant flow from the slab to the air node during November and the Albany location shows three additional months in which more energy is moving from the slab to the air node than the reverse.

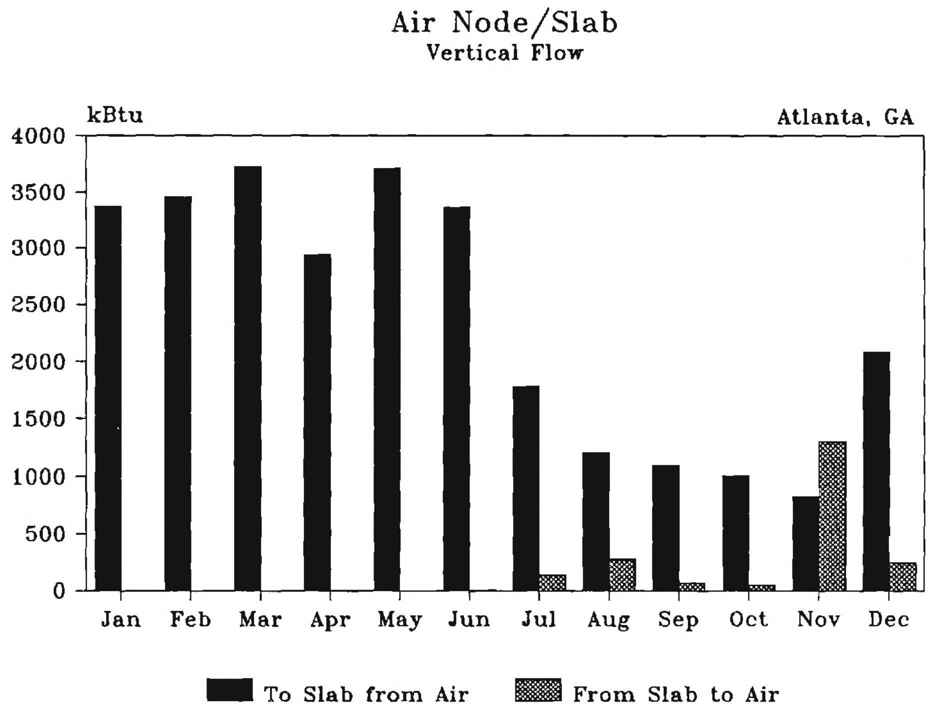
Figures 4.6 and 4.7 indicate energy movement through the eight inch above grade slab assembly exposed edge. The flows are a substantial percentage of the corresponding monthly air node/slab flows. At both locations the flows through the exposed edge to ambient conditions during the last three months of the year are greater than the corresponding flows from the air node to the slab. This phenomenon is most likely a reflection of a decrease in field temperatures attributed with moving from the cooling to the heating season.

Figures 4.8 through 4.11 isolate vertical energy movement at the slab-soil interface for the entire slab, the first four feet, and the first two feet at the perimeter. The majority of the movement occurs in the vertical downward direction from slab assembly to soil field. Both locations show some downward flow for all months of the year and some smaller upward movement for the latter half of the year. Note that during the heating months the flows at the first four and two feet about the perimeter are greater than fifty percent of the total slab flows.

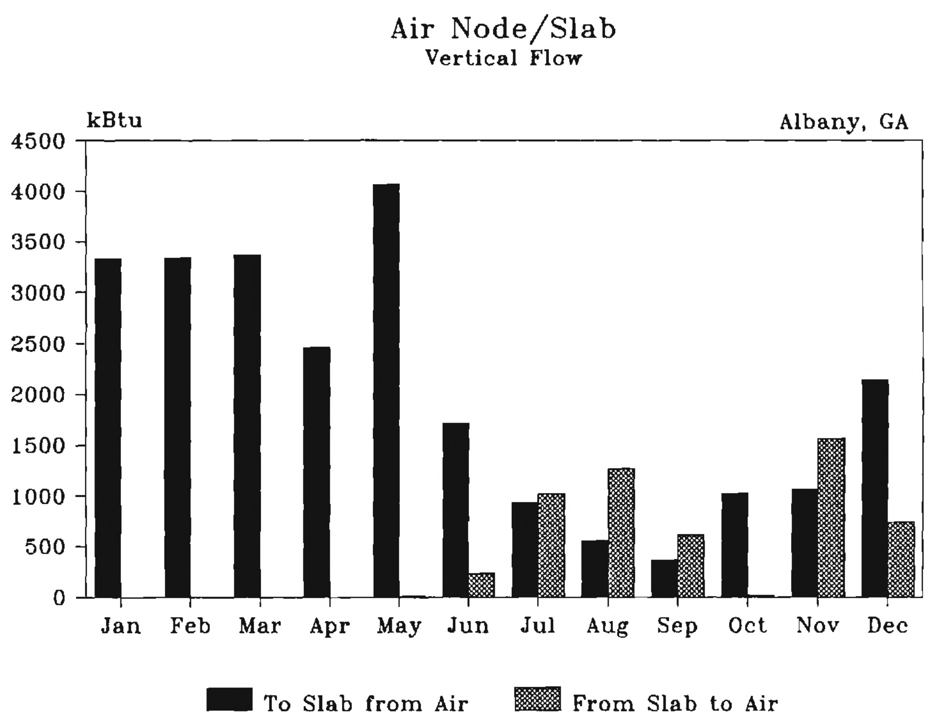
Figures 4.12 through 4.15 indicate horizontal energy flow about the vertical foundation wall. Flows were isolated at typical insulation placement areas; at the interior from bottom of slab to top of footing and at the exterior from top of slab to top of footing. The energy movement at the exterior is notably higher due to the inclusion of the additional eight inches of above grade exposed edge.

Figures 4.16 and 4.17 indicate the summation of all horizontal movement of energy passing through the vertical below the foundation wall. The flows are substantially less than those above and are mostly moving in a direction away from the slab.

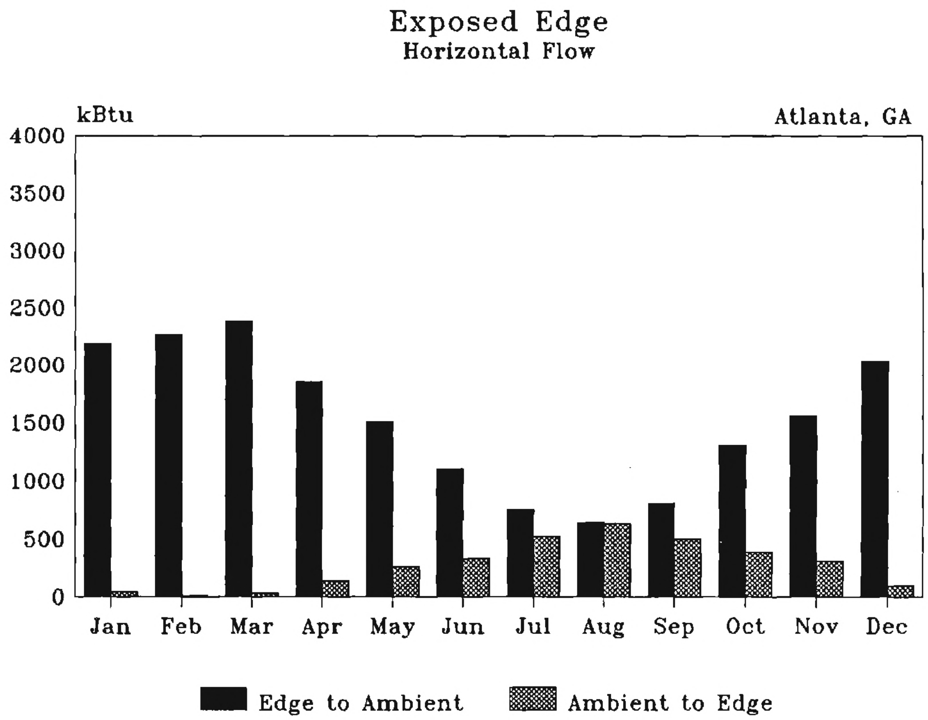
The last pair of figures, 4.18 and 4.19 indicate energy movement to the nodes simulating a larger mass of soil at the bottom and side of the model. Movement to the side of the model is almost negligible and movement to the bottom appears to be a cooling season occurrence.



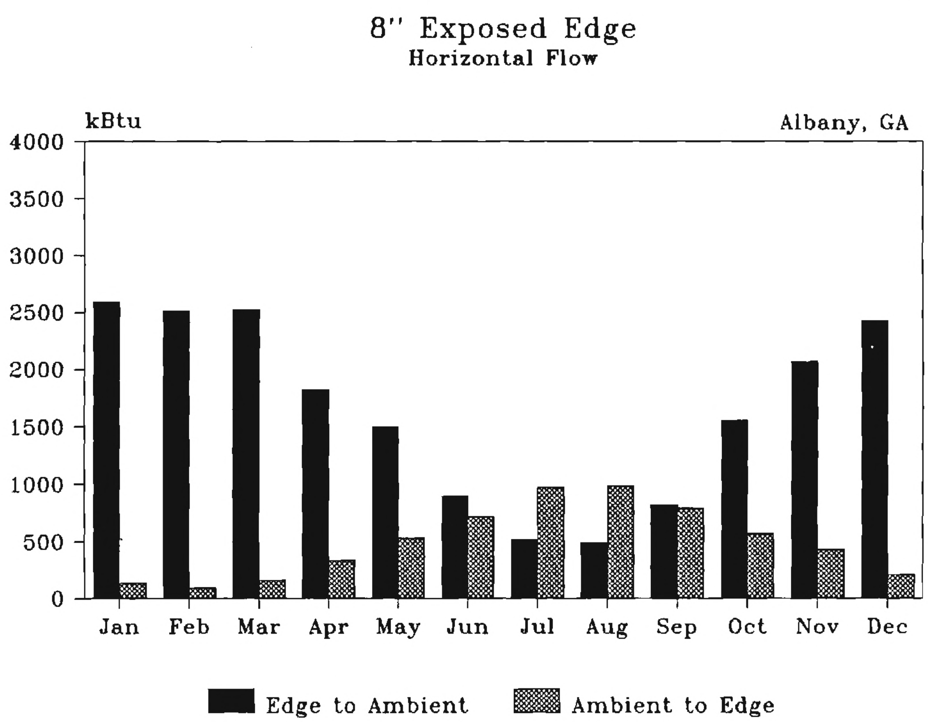
Air Node/Slab Flow **Figure 4.4**



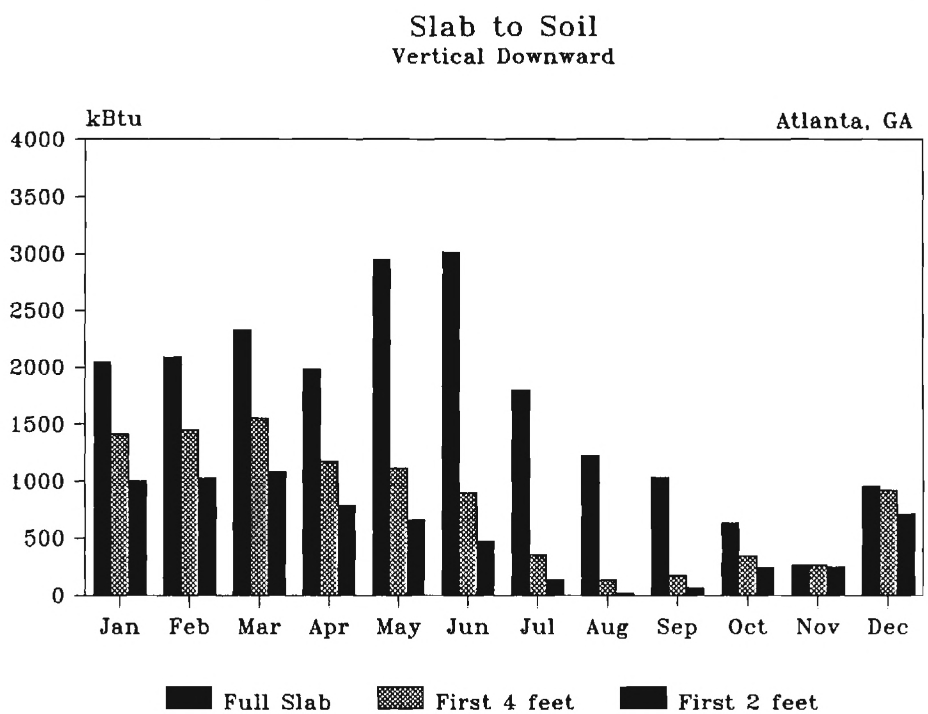
Air Node/Slab Flow **Figure 4.5**



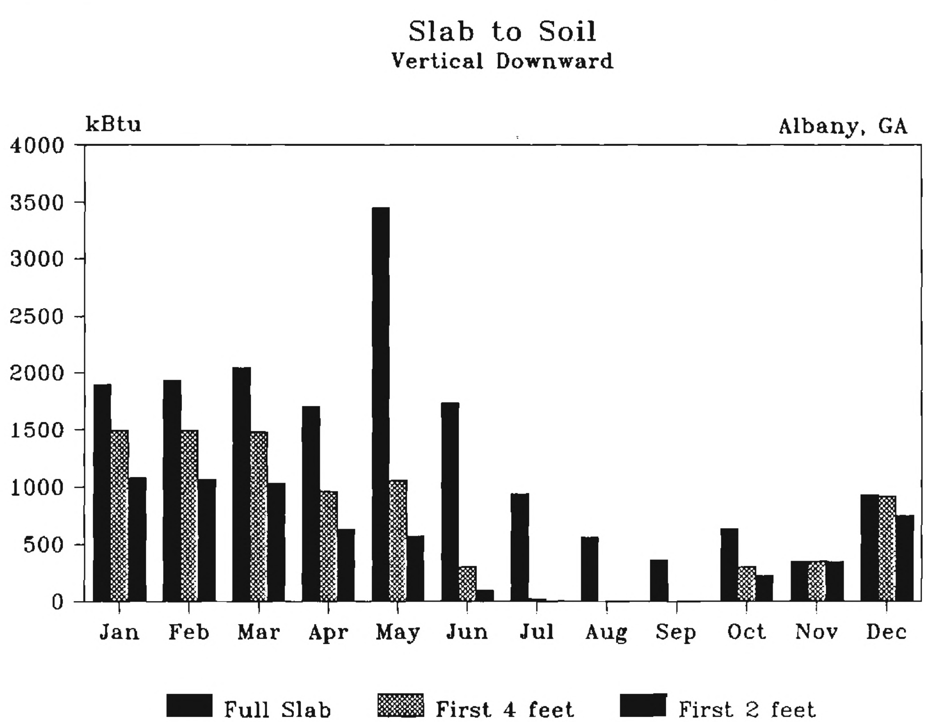
Exposed Edge Flow **Figure 4.6**



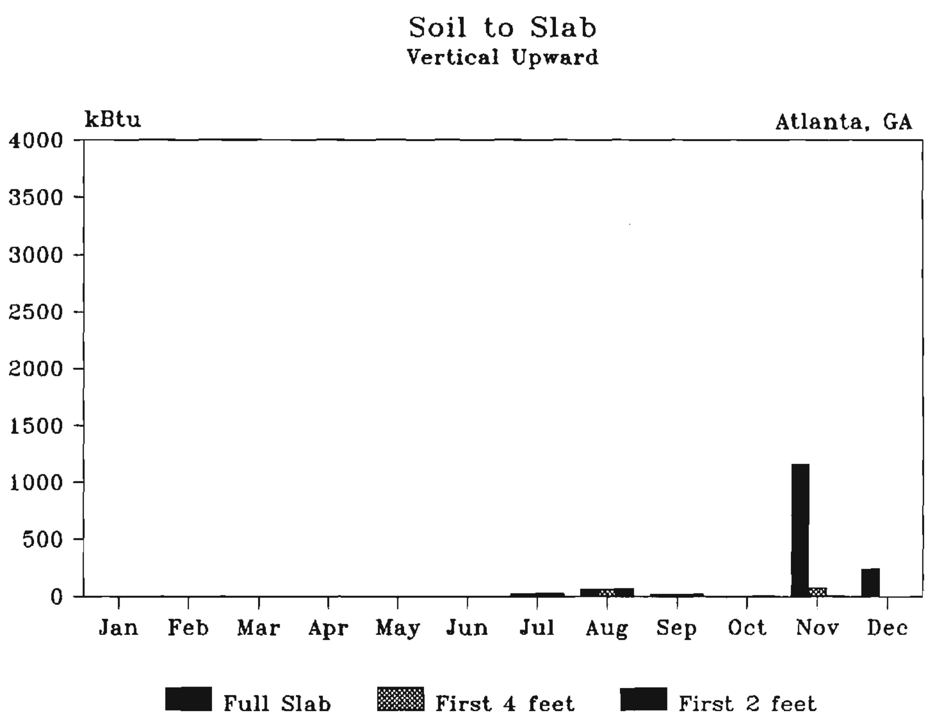
Exposed Edge Flow **Figure 4.7**



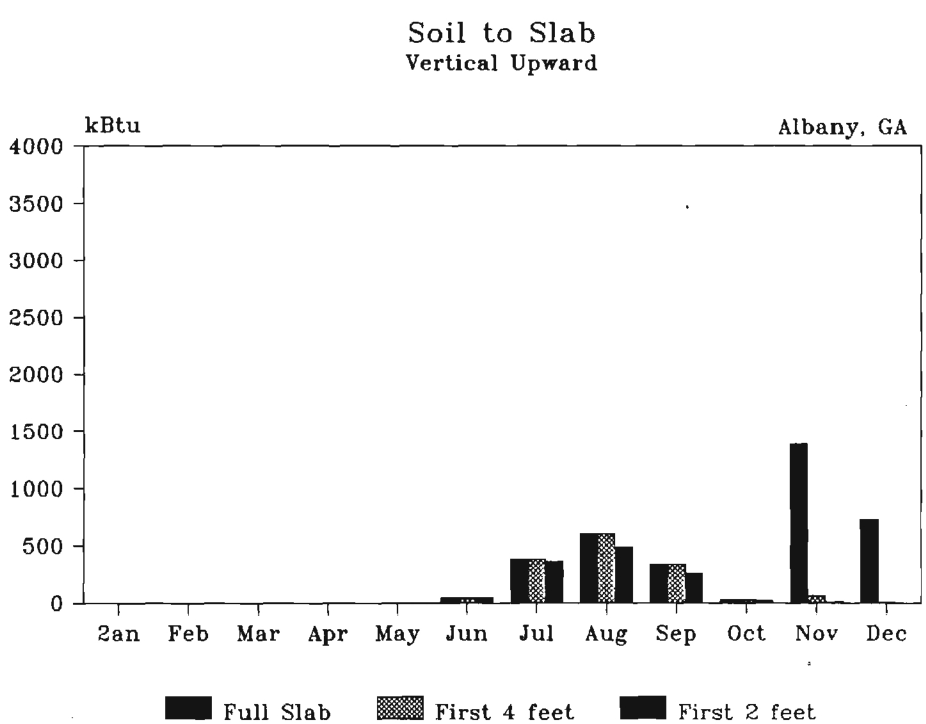
Slab to Soil **Figure 4.8**



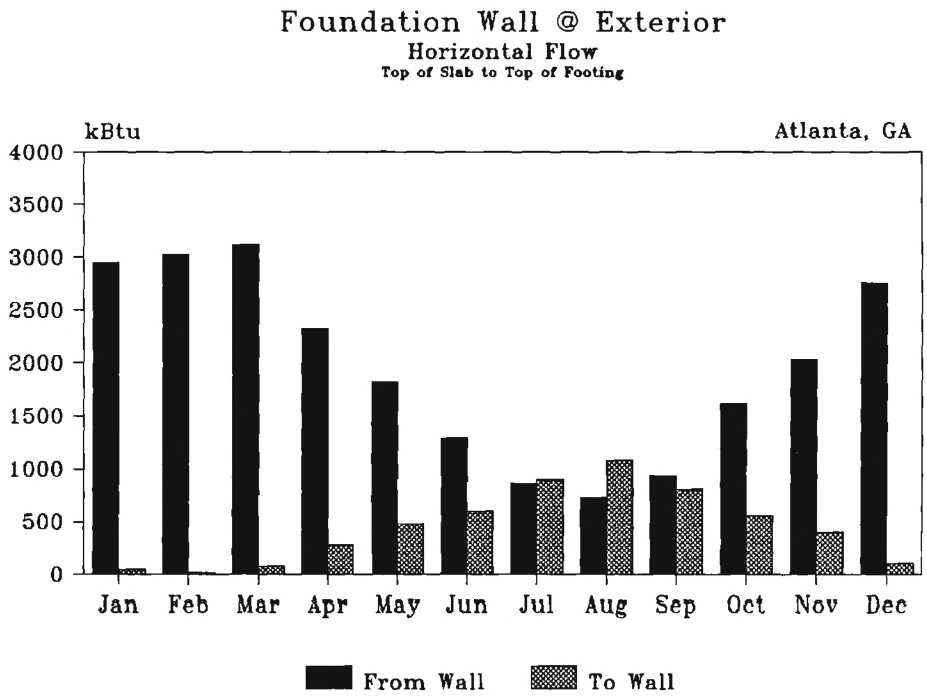
Slab to Soil Flow **Figure 4.9**



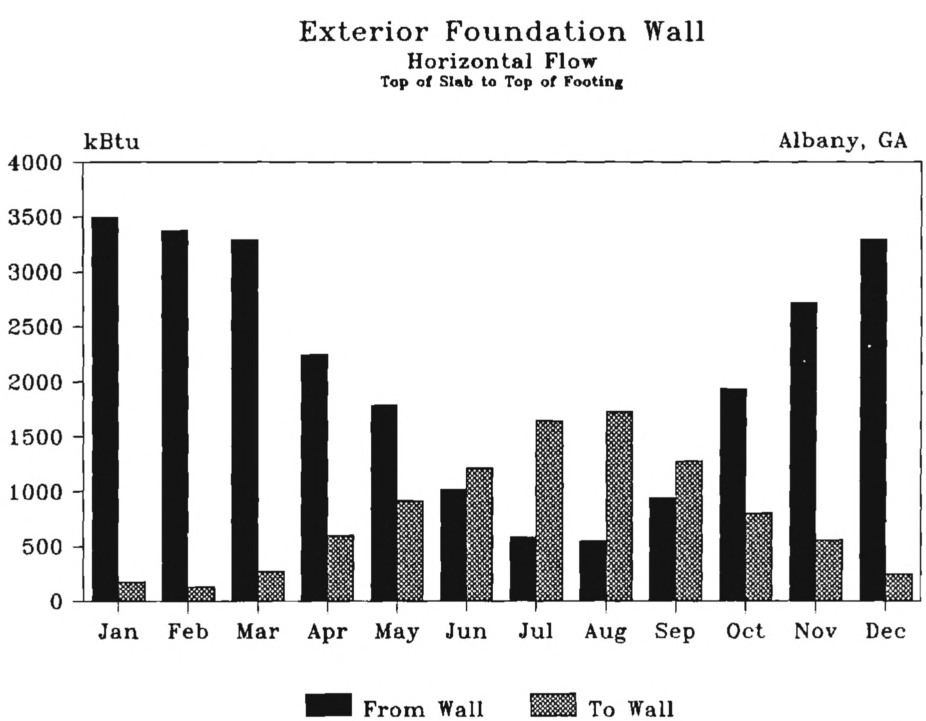
Soil to Slab Flow **Figure 4.10**



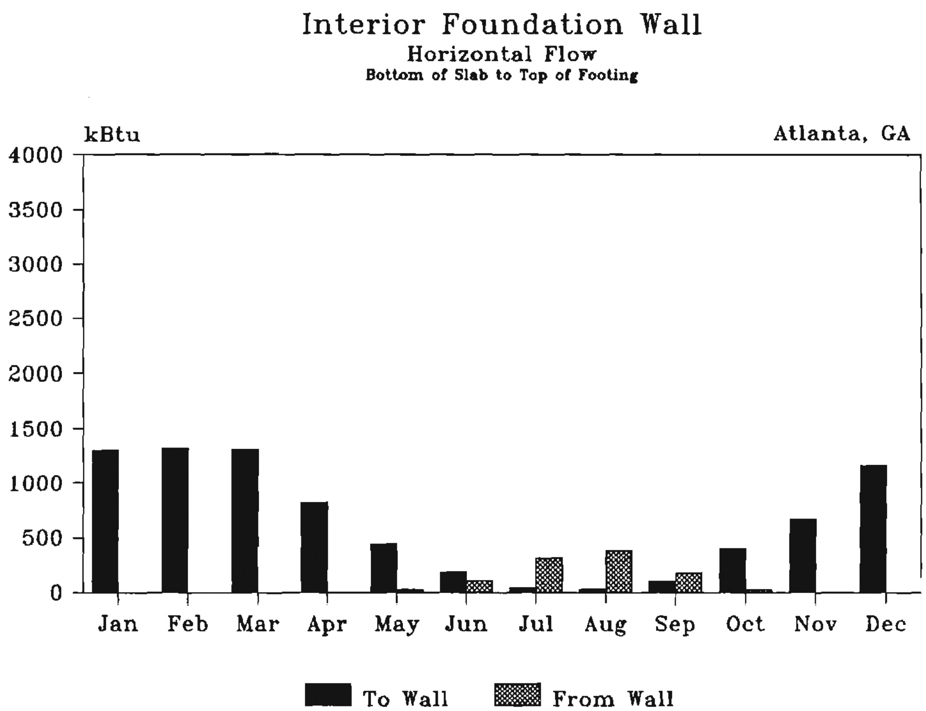
Soil to Slab Flow **Figure 4.11**



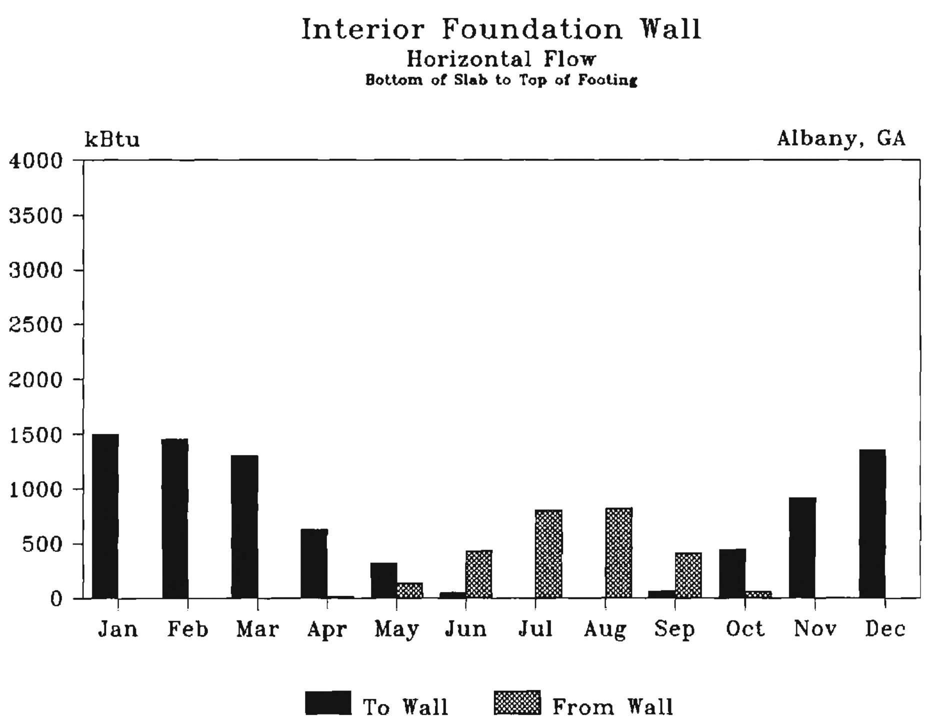
Flow at Exterior Foundation Wall **Figure 4.12**



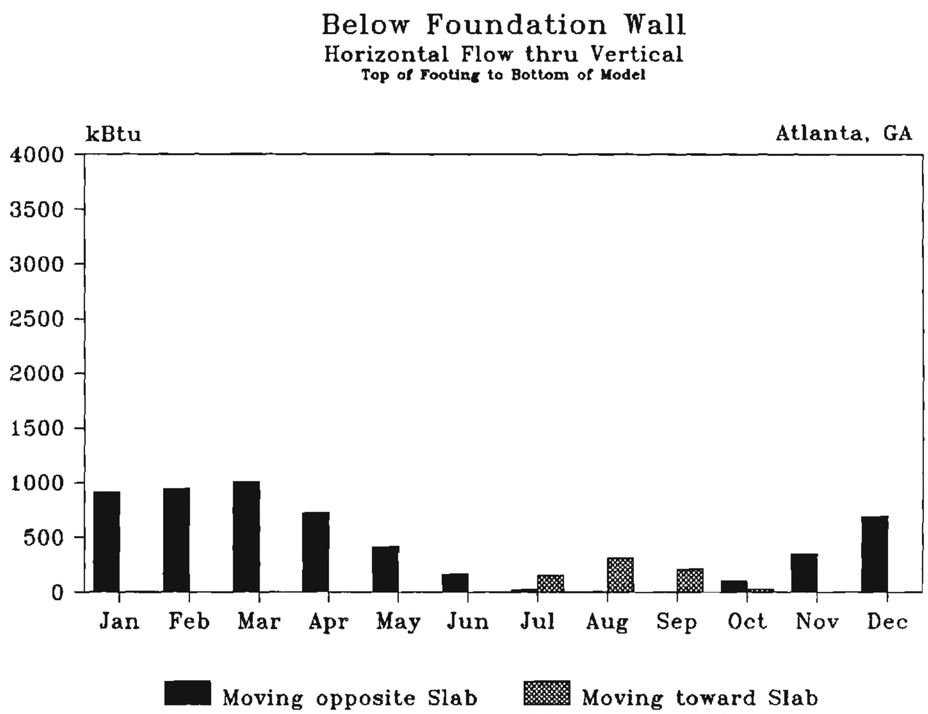
Flow at Exterior Foundation Wall **Figure 4.13**



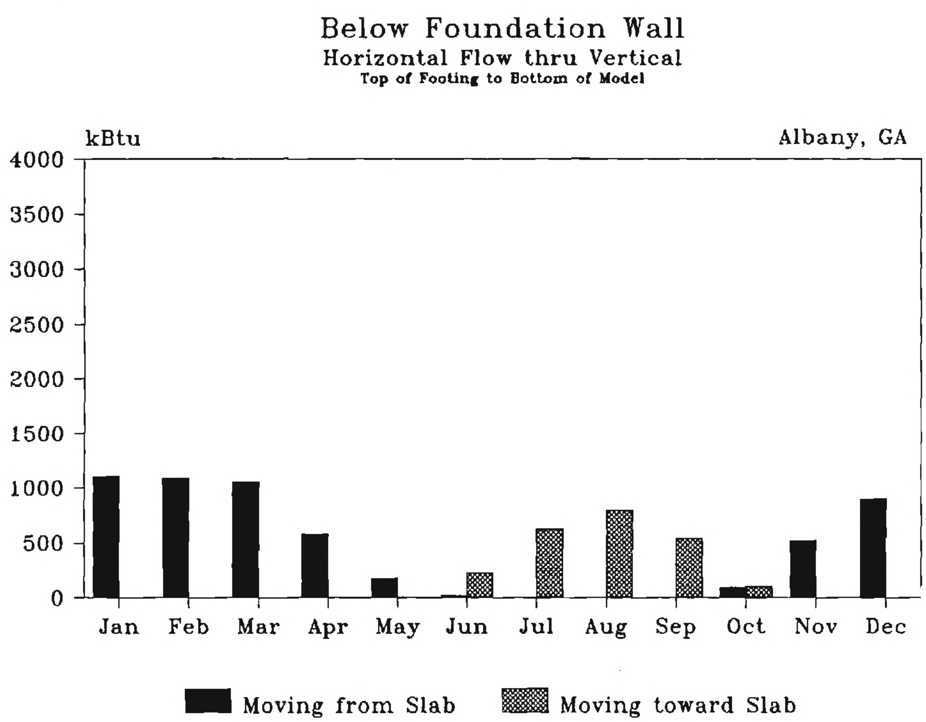
Flow at Interior Foundation Wall **Figure 4.14**



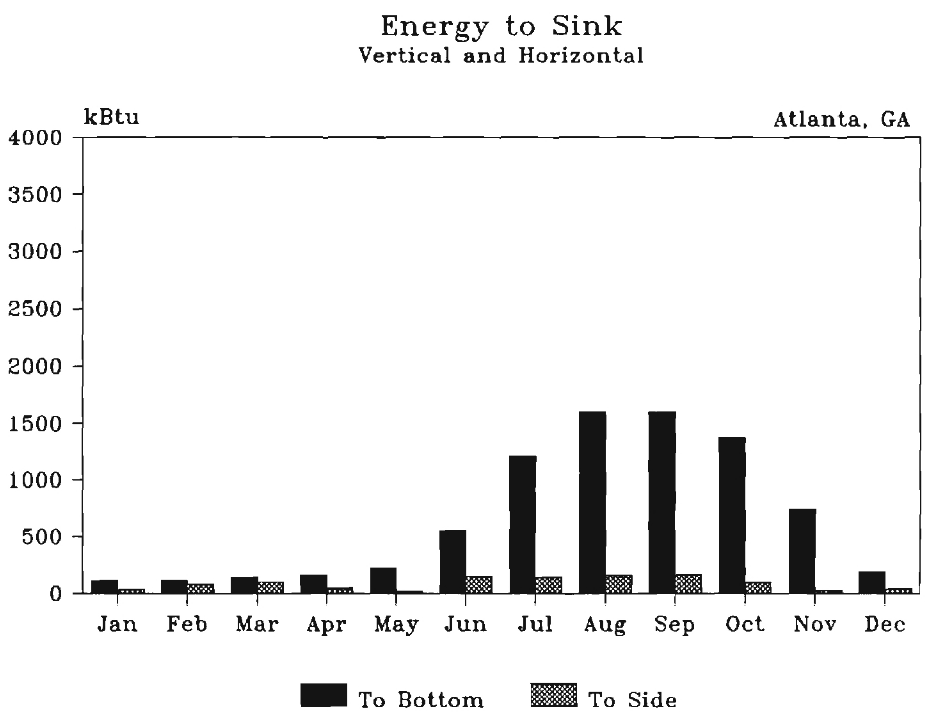
Flow at Interior Foundation Wall **Figure 4.15**



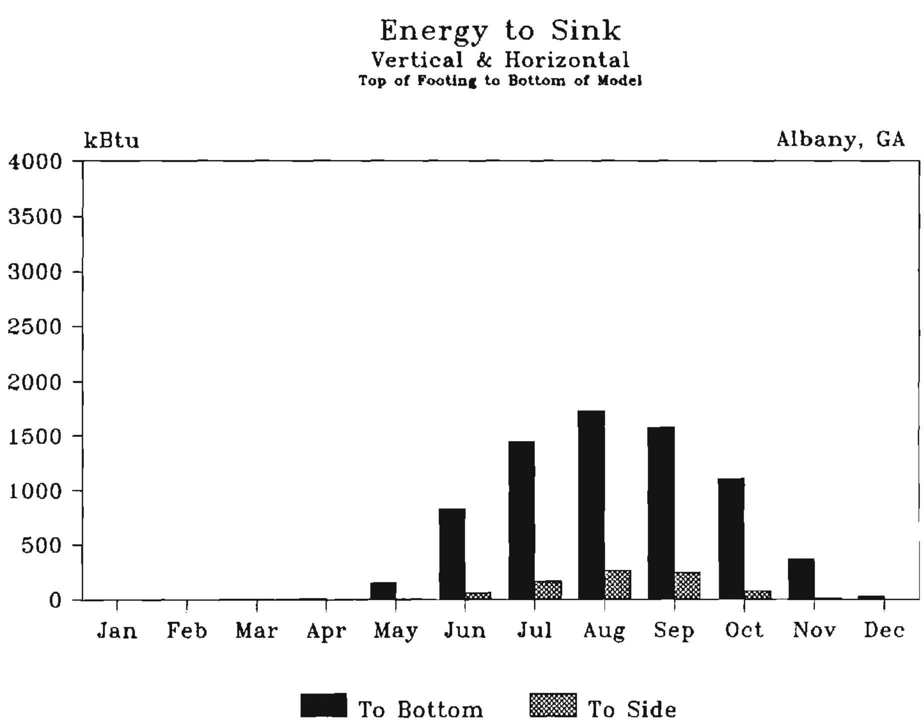
Flow through Vertical Below Wall **Figure 4.16**



Flow through Vertical below Wall **Figure 4.17**



Flow to Sink **Figure 4.18**



Flow to Sink **Figure 4.19**

References

1. CALPAS III, Berkeley Solar Group, Berkeley, CA, 1982.

2. Cleaveland, J., LOADCAL, A Microcomputer Simulation, Masters thesis, Georgia Institute of Technology, 1980.

3. "Weather for Typical Meterological Year", National Oceanographic and Atmospheric Administration, Ashville, NC.

4. Fundamentals Handbook, American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc., Atlanta, GA, 1981.

5. Labs, K.,"Underground Building Climate", Solar Age, Volume 4 Number 10, October 1979.

6. Cooling and Heating Load Calculation Manual, ASHRAE GRP 158, American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA, no date.

7. "Styrofoam Brand Insulation Products for Walls, Foundations and Roofs", D0/7.14, Fabricated Products Division, Dow Chemical, U.S.A., 1987

Insulation Placement Strategies

Insulation Placement Simulation

Seventeen strategies of various insulation placement were modeled and compared with the base case of no insulation. Each of the simulations occurs in one of three categories, vertical placement at the exterior foundation wall from top of slab to top of footing, vertical insulation placement at the interior foundation wall from the bottom of slab to the top of footing, or horizontal placement below the slab from the inside of the foundation wall into the interior for a distance of two and four feet. Each major category considers three levels of insulation, one-half inch thick (R 2.5), one inch thick (R 5.0), and two inches thick (R 10.0).

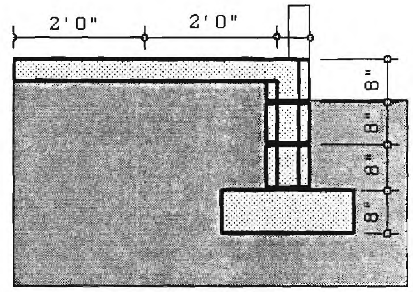
Individual pages describing each situation follow including a tabular and graphic depiction of the effect of that particular placement of insulation relative to the no insulation base case.

Atlanta, GA

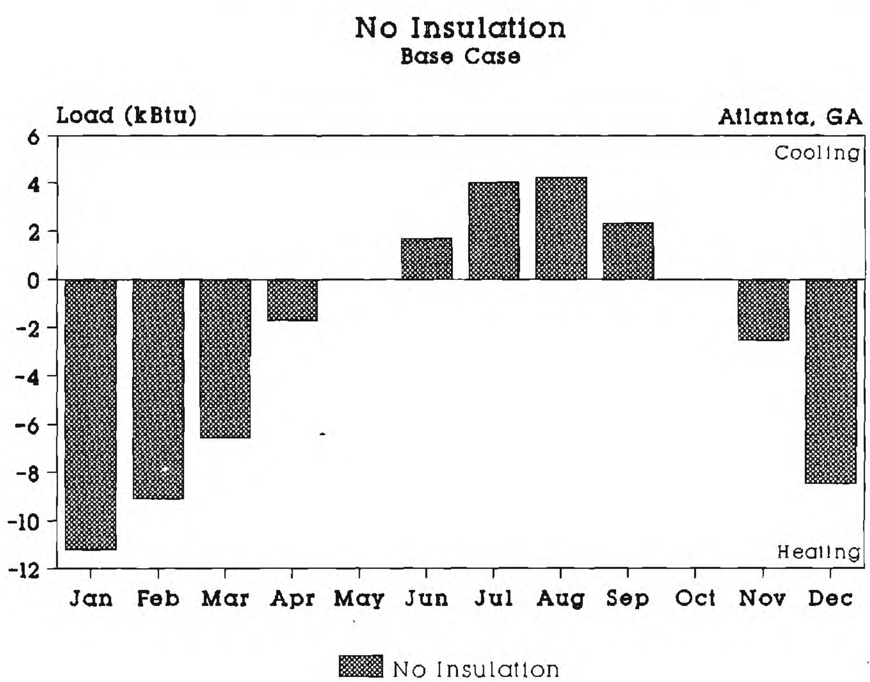
No Insulation

Base case

8" exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	(%Tot)	Slab Edge Heat Loss (kBtu)	(%Slb)	Slab Cooling Contribution (kBtu)	(%Tot)
Ann	39,526	0	12,248	0	16,049	40.6	9,222	57.5	486	4.0
Jan	11,210	0	0	0	3,314	29.6	1,950	58.8	0	0.0
Feb	9,103	0	0	0	3,415	37.5	2,028	59.4	0	0.0
Mar	6,550	0	0	0	3,690	56.3	2,261	61.3	0	0.0
Apr	1,705	0	0	0	2,908	0.0	1,890	65.0	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	1,698	0	0	0.0	0	0.0	4	0.3
Jul	0	0	4,020	0	0	0.0	0	0.0	138	3.4
Aug	0	0	4,206	0	0	0.0	0	0.0	277	6.6
Sep	0	0	2,323	0	0	0.0	0	0.0	66	2.8
Oct	0	0	0	0	0	0.0	0	0.0	0	0.0
Nov	2,503	0	0	0	640	25.6	167	26.1	0	0.0
Dec	8,454	0	0	0	2,082	24.6	926	44.5	0	0.0

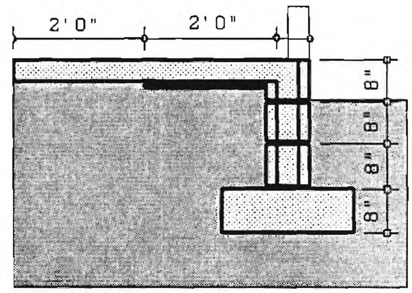


Atlanta, GA

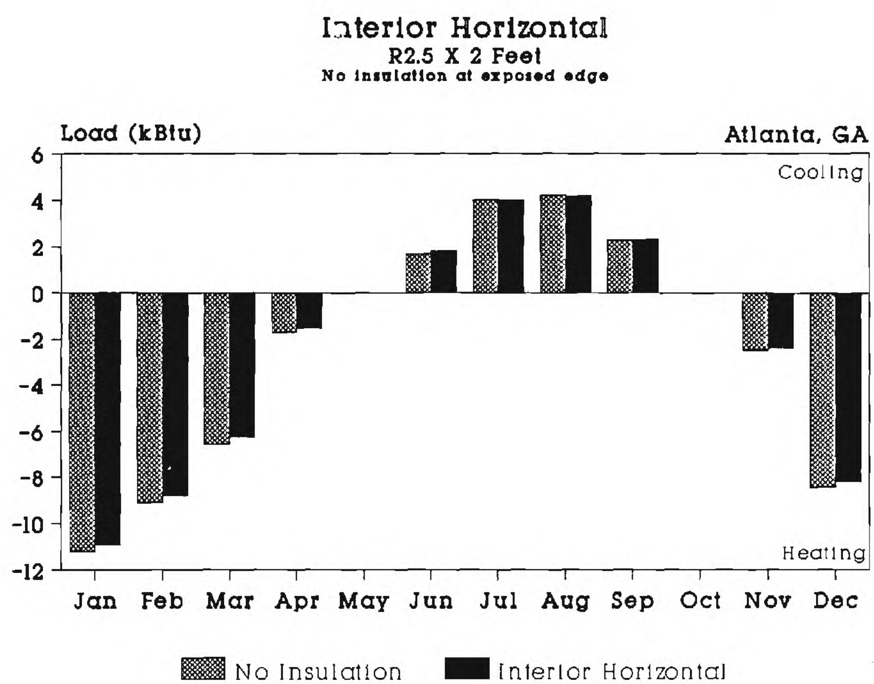
Interior Horizontal

R2.5 X 2 Feet

No insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	38,067	1,459	12,377	(129)	14,606	38.4	7,206	49.3	473	3.8
Jan	10,910	300	0	0	3,014	27.6	1,532	50.8	0	0.0
Feb	8,801	302	0	0	3,112	35.4	1,607	51.6	0	0.0
Mar	6,243	307	0	0	3,382	54.2	1,828	54.0	0	0.0
Apr	1,507	198	0	0	2,706	0.0	1,599	59.1	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	1,824	(126)	0	0.0	0	0.0	5	0.3
Jul	0	0	4,028	(7)	0	0.0	0	0.0	138	3.4
Aug	0	0	4,194	13	0	0.0	0	0.0	262	6.2
Sep	0	0	2,332	(8)	0	0.0	0	0.0	67	2.9
Oct	0	0	0	0	0	0.0	0	0.0	0	0.0
Nov	2,398	105	0	0	559	23.3	53	9.4	0	0.0
Dec	8,208	246	0	0	1,832	22.3	588	32.1	0	0.0

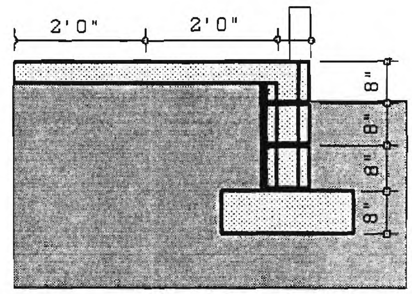


Atlanta, GA

Interior Vertical

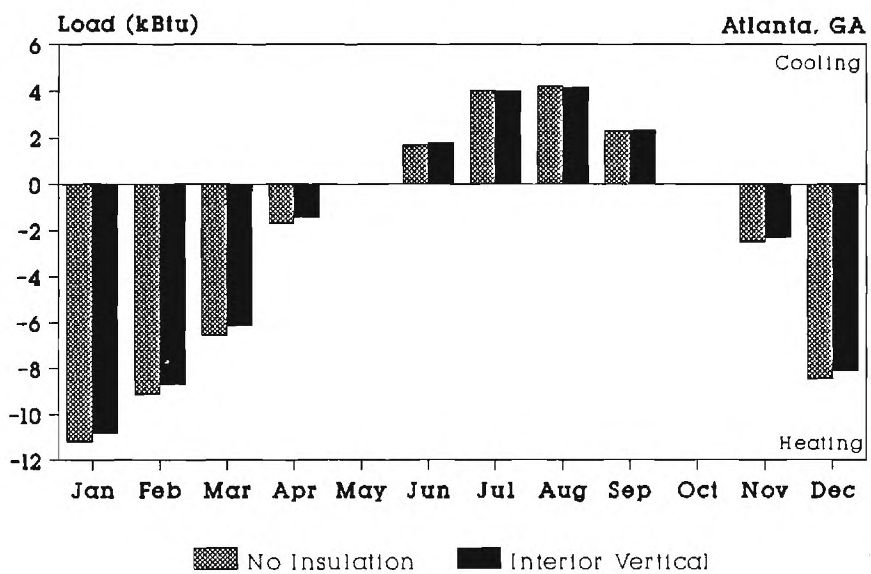
R2.5 X Full Height

No insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	37,545	1,980	12,278	(30)	14,151	37.7	6,523	46.1	417	3.4
Jan	10,821	390	0	0	2,924	27.0	1,396	47.7	0	0.0
Feb	8,708	395	0	0	3,018	34.7	1,467	48.6	0	0.0
Mar	6,144	406	0	0	3,283	53.4	1,687	51.4	0	0.0
Apr	1,441	264	0	0	2,641	0.0	1,506	57.0	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	1,796	(98)	0	0.0	0	0.0	5	0.3
Jul	0	0	4,001	19	0	0.0	0	0.0	123	3.1
Aug	0	0	4,165	41	0	0.0	0	0.0	231	5.5
Sep	0	0	2,316	8	0	0.0	0	0.0	58	2.5
Oct	0	0	0	0	0	0.0	0	0.0	0	0.0
Nov	2,314	189	0	0	525	22.7	4	0.8	0	0.0
Dec	8,119	336	0	0	1,759	21.7	462	26.3	0	0.0

Interior Vertical
R2.5 X Full Height
No insulation at exposed edge

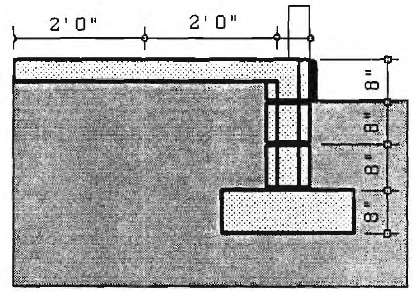


Atlanta, GA

Exposed Edge

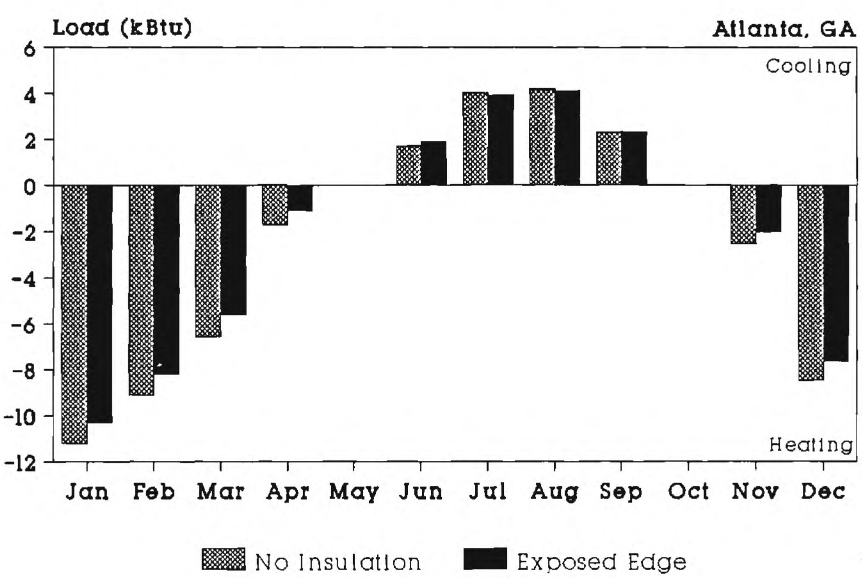
R2.5 X 8 Inches

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	34,827	4,698	12,326	(77)	11,543	33.1	6,592	57.1	165	1.3
Jan	10,310	901	0	0	2,415	23.4	1,380	57.2	0	0.0
Feb	8,181	922	0	0	2,492	30.5	1,437	57.7	0	0.0
Mar	5,604	946	0	0	2,743	49.0	1,663	60.6	0	0.0
Apr	1,077	628	0	0	2,273	0.0	1,536	67.6	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	1,905	(206)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,959	61	0	0.0	0	0.0	21	0.5
Aug	0	0	4,117	89	0	0.0	0	0.0	131	3.2
Sep	0	0	2,341	(18)	0	0.0	0	0.0	13	0.6
Oct	0	0	4	(4)	0	0.0	0	0.0	0	0.0
Nov	2,010	493	0	0	320	15.9	79	24.7	0	0.0
Dec	7,646	809	0	0	1,300	17.0	496	38.1	0	0.0

Exposed Edge
R2.5 X 8 Inches
R2.5 insulation at exposed edge

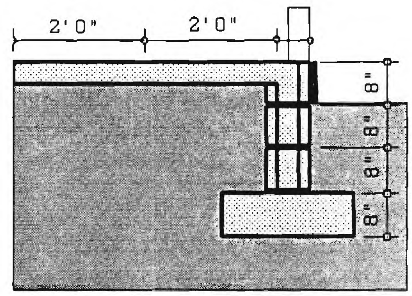


Atlanta, GA

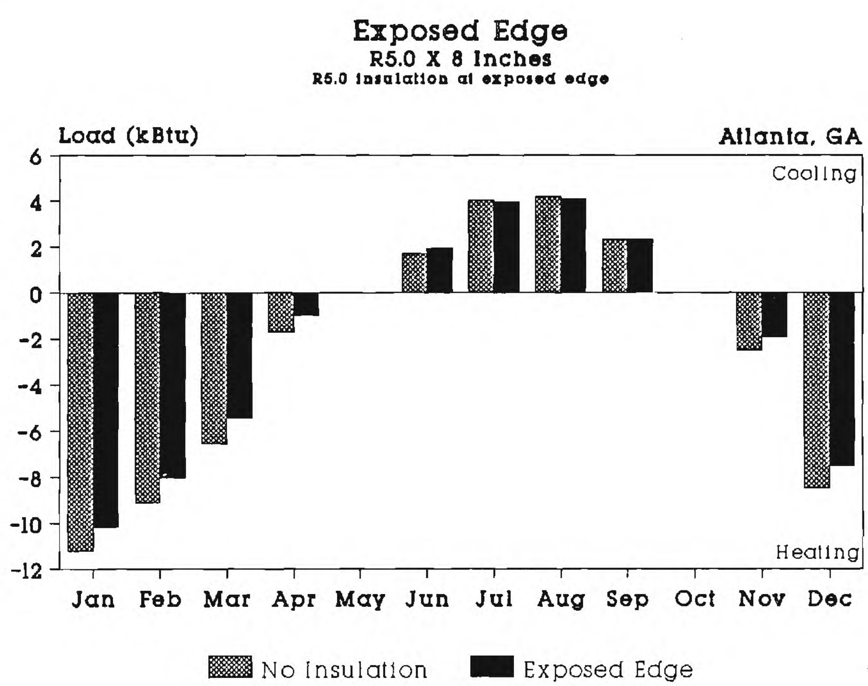
Exposed Edge

R5.0 X 8 Inches

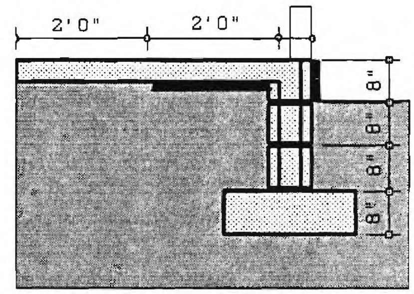
R5.0 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	34,092	5,434	12,375	(127)	10,840	31.8	5,923	54.6	146	1.2
Jan	10,172	1,038	0	0	2,277	22.4	1,249	54.9	0	0.0
Feb	8,039	1,064	0	0	2,351	29.2	1,300	55.3	0	0.0
Mar	5,456	1,095	0	0	2,594	47.5	1,520	58.6	0	0.0
Apr	976	729	0	0	2,171	0.0	1,439	66.3	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	1,952	(254)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,960	60	0	0.0	0	0.0	15	0.4
Aug	0	0	4,110	96	0	0.0	0	0.0	118	2.9
Sep	0	0	2,348	(25)	0	0.0	0	0.0	13	0.6
Oct	0	0	4	(4)	0	0.0	0	0.0	0	4.2
Nov	1,928	575	0	0	267	13.8	35	13.0	0	0.0
Dec	7,521	933	0	0	1,180	15.7	381	32.3	0	0.0



Atlanta, GA

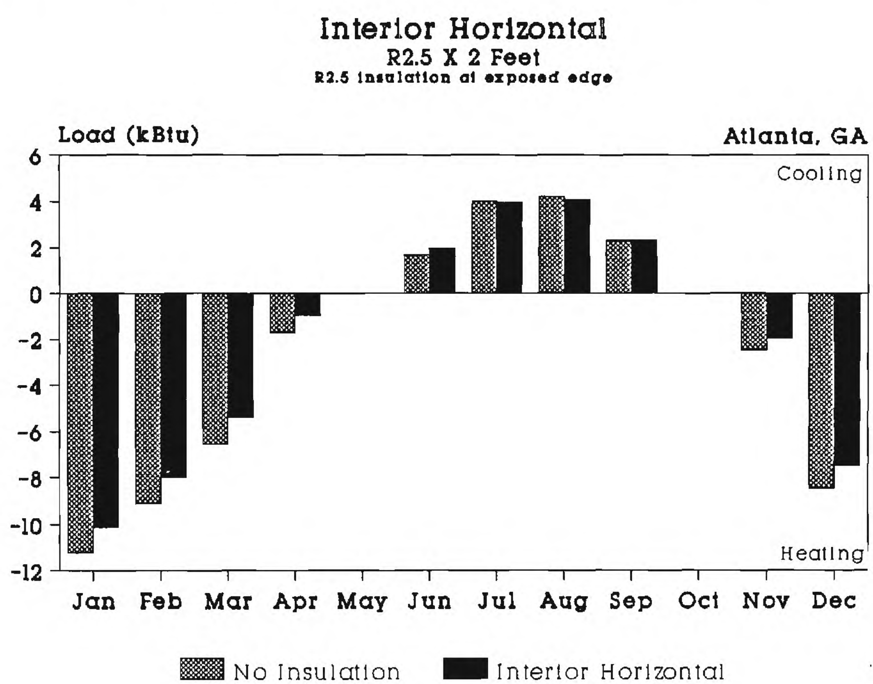


Interior Horizontal

R2.5 X 2 Feet

R2.5 insulation at exposed edge

	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	33,928	5,598	12,412	(164)	10,645	31.4	5,284	49.6	152	1.2
Jan	10,120	1,090	0	0	2,225	22.0	1,106	49.7	0	0.0
Feb	7,988	1,114	0	0	2,299	28.8	1,157	50.3	0	0.0
Mar	5,410	1,140	0	0	2,548	47.1	1,376	54.0	0	0.0
Apr	956	749	0	0	2,150	0.0	1,346	62.6	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	1,998	(299)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,964	56	0	0.0	0	0.0	20	0.5
Aug	0	0	4,103	104	0	0.0	0	0.0	119	2.9
Sep	0	0	2,344	(21)	0	0.0	0	0.0	12	0.5
Oct	0	0	4	(4)	0	0.0	0	0.0	0	4.8
Nov	1,959	545	0	0	278	14.2	17	6.1	0	0.0
Dec	7,495	959	0	0	1,145	15.3	281	24.6	0	0.0

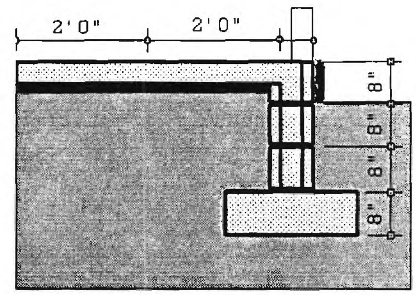


Atlanta, GA

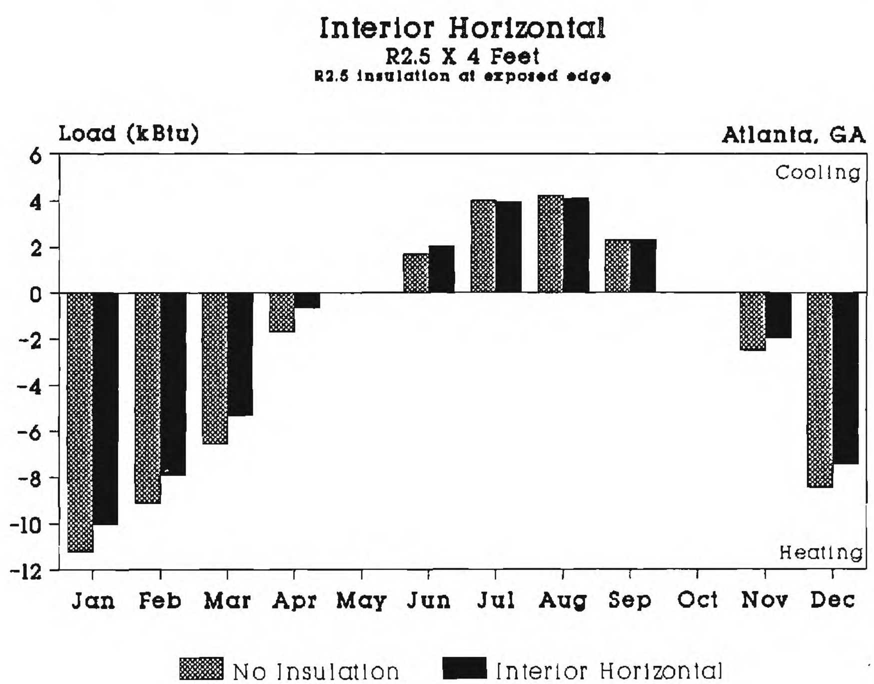
Interior Horizontal

R2.5 X 4 Feet

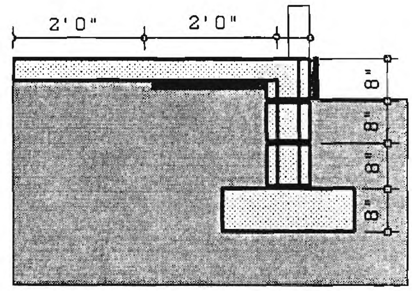
R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	33,327	6,199	12,515	(266)	9,610	28.8	4,454	46.3	144	1.2
Jan	10,036	1,174	0	0	2,140	21.3	1,012	47.3	0	0.0
Feb	7,903	1,200	0	0	2,214	28.0	1,061	47.9	0	0.0
Mar	5,322	1,228	0	0	2,460	46.2	1,276	51.9	0	0.0
Apr	650	1,055	0	0	1,434	0.0	875	61.0	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	2,080	(382)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,978	42	0	0.0	0	0.0	18	0.5
Aug	0	0	4,103	103	0	0.0	0	0.0	114	2.8
Sep	0	0	2,349	(26)	0	0.0	0	0.0	11	0.5
Oct	0	0	4	(4)	0	0.0	0	0.0	0	9.3
Nov	1,974	529	0	0	274	13.9	12	4.3	0	0.0
Dec	7,442	1,013	0	0	1,086	14.6	217	20.0	0	0.0



Atlanta, GA

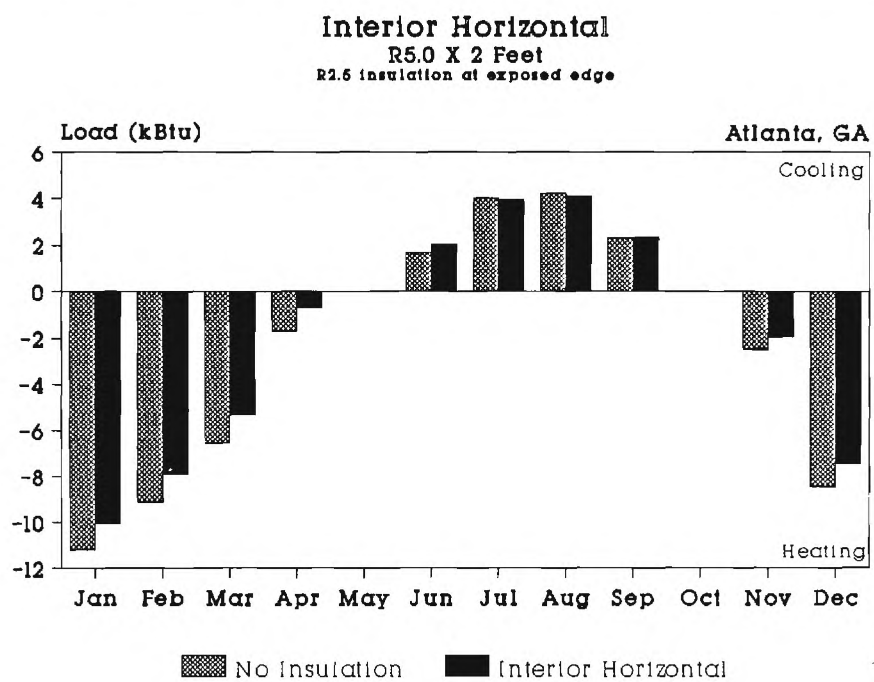


Interior Horizontal

R5.0 X 2 Feet

R2.5 insulation at exposed edge

	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	33,403	6,122	12,452	(203)	9,795	29.3	4,459	45.5	151	1.2
Jan	10,050	1,160	0	0	2,155	21.4	1,000	46.4	0	0.0
Feb	7,917	1,185	0	0	2,229	28.2	1,045	46.9	0	0.0
Mar	5,338	1,212	0	0	2,476	46.4	1,261	50.9	0	0.0
Apr	712	993	0	0	1,578	0.0	951	60.3	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	2,038	(340)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,967	53	0	0.0	0	0.0	21	0.5
Aug	0	0	4,098	108	0	0.0	0	0.0	117	2.9
Sep	0	0	2,345	(22)	0	0.0	0	0.0	12	0.5
Oct	0	0	4	(4)	0	0.0	0	0.0	0	4.8
Nov	1,944	559	0	0	266	13.7	(1)	-0.3	0	0.0
Dec	7,442	1,012	0	0	1,090	14.6	202	18.5	0	0.0

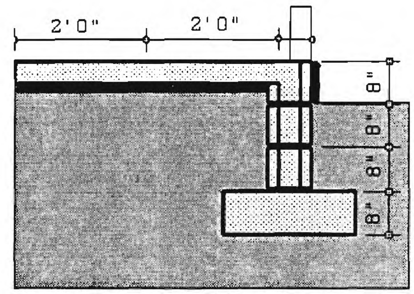


Atlanta, GA

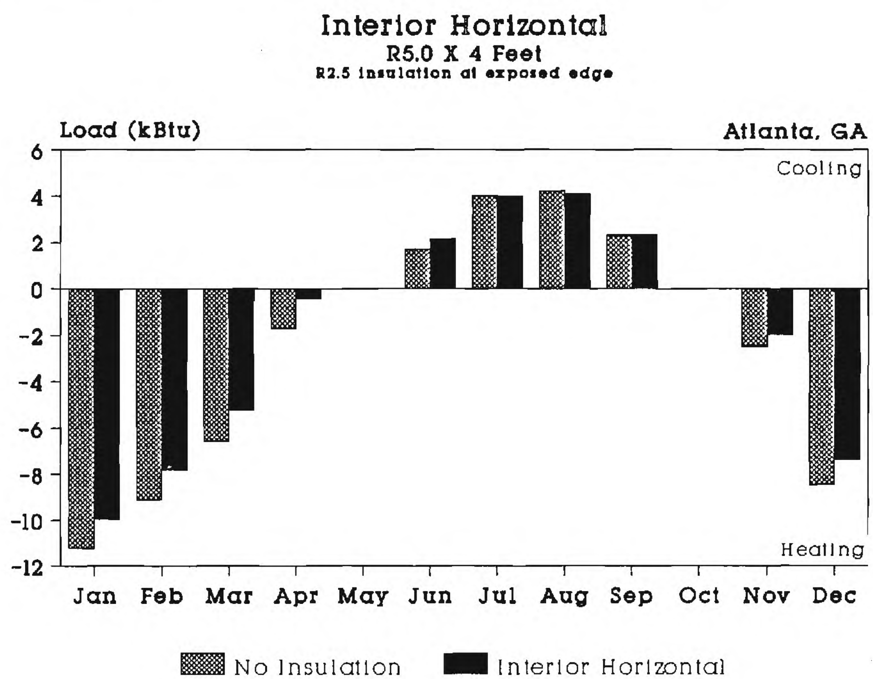
Interior Horizontal

R5.0 X 4 Feet

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	32,722	6,804	12,622	(374)	8,701	26.6	3,530	40.6	142	1.1
Jan	9,941	1,270	0	0	2,045	20.6	870	42.5	0	0.0
Feb	7,798	1,304	0	0	2,110	27.1	910	43.1	0	0.0
Mar	5,208	1,342	0	0	2,346	45.0	1,116	47.6	0	0.0
Apr	428	1,277	0	0	925	0.0	529	57.2	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	2,175	(476)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,992	28	0	0.0	0	0.0	18	0.4
Aug	0	0	4,100	106	0	0.0	0	0.0	112	2.7
Sep	0	0	2,352	(28)	0	0.0	0	0.0	12	0.5
Oct	0	0	4	(4)	0	0.0	0	0.0	0	9.3
Nov	1,975	528	0	0	266	13.5	(6)	-2.3	0	0.0
Dec	7,371	1,083	0	0	1,009	13.7	112	11.0	0	0.0

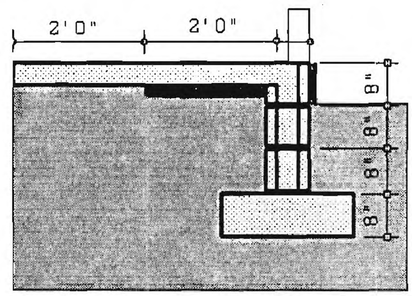


Atlanta, GA

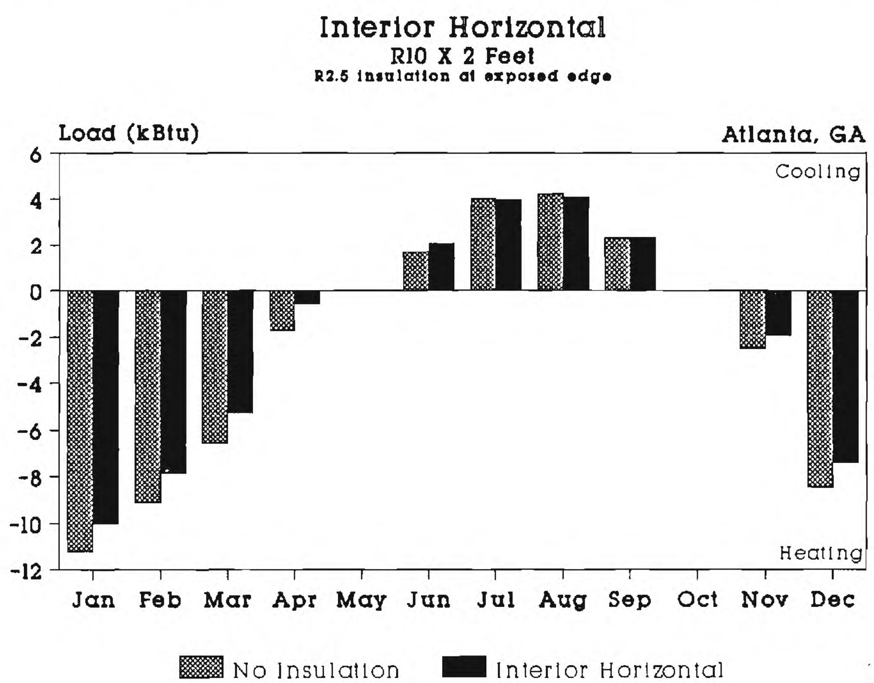
Interior Horizontal

R10 X 2 Feet

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	33,028	6,497	12,487	(239)	9,217	27.9	3,860	41.9	156	1.2
Jan	10,002	1,209	0	0	2,107	21.1	914	43.4	0	0.0
Feb	7,861	1,242	0	0	2,173	27.6	954	43.9	0	0.0
Mar	5,276	1,275	0	0	2,414	45.8	1,162	48.1	0	0.0
Apr	558	1,147	0	0	1,219	0.0	707	58.0	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	2,076	(378)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,971	50	0	0.0	0	0.0	23	0.6
Aug	0	0	4,093	114	0	0.0	0	0.0	119	2.9
Sep	0	0	2,344	(21)	0	0.0	0	0.0	14	0.6
Oct	0	0	4	(4)	0	0.0	0	0.0	0	9.5
Nov	1,934	569	0	0	259	13.4	(12)	-4.8	0	0.0
Dec	7,399	1,056	0	0	1,045	14.1	135	12.9	0	0.0

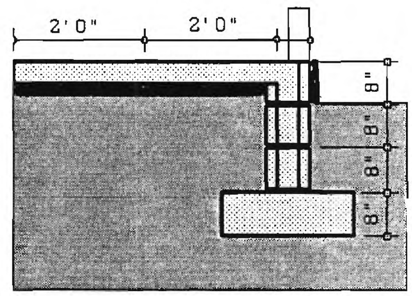


Atlanta, GA

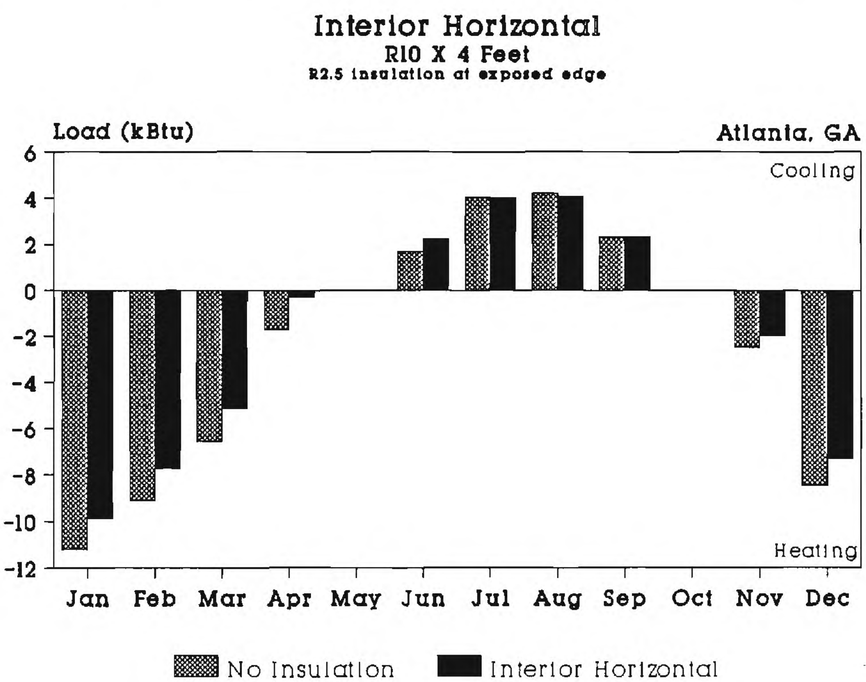
Interior Horizontal

R10 X 4 Feet

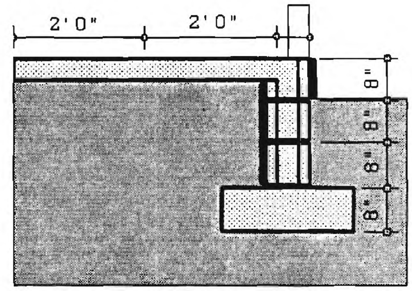
R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	32,124	7,402	12,721	(473)	7,858	24.3	2,680	34.1	143	1.1
Jan	9,832	1,378	0	0	1,937	19.6	721	37.2	0	0.0
Feb	7,689	1,414	0	0	2,000	25.9	753	37.6	0	0.0
Mar	5,134	1,458	0	0	2,234	43.5	953	42.6	0	0.0
Apr	389	1,316	0	0	498	0.0	262	52.7	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	2,262	(564)	0	0.0	0	0.0	0	0.0
Jul	0	0	4,004	17	0	0.0	0	0.0	18	0.5
Aug	0	0	4,097	109	0	0.0	0	0.0	112	2.7
Sep	0	0	2,355	(31)	0	0.0	0	0.0	12	0.5
Oct	0	0	4	(4)	0	0.0	0	0.0	1	18.0
Nov	1,963	540	0	0	256	13.0	(20)	-7.9	0	0.0
Dec	7,304	1,158	0	0	933	12.8	12	1.2	0	0.0



Atlanta, GA

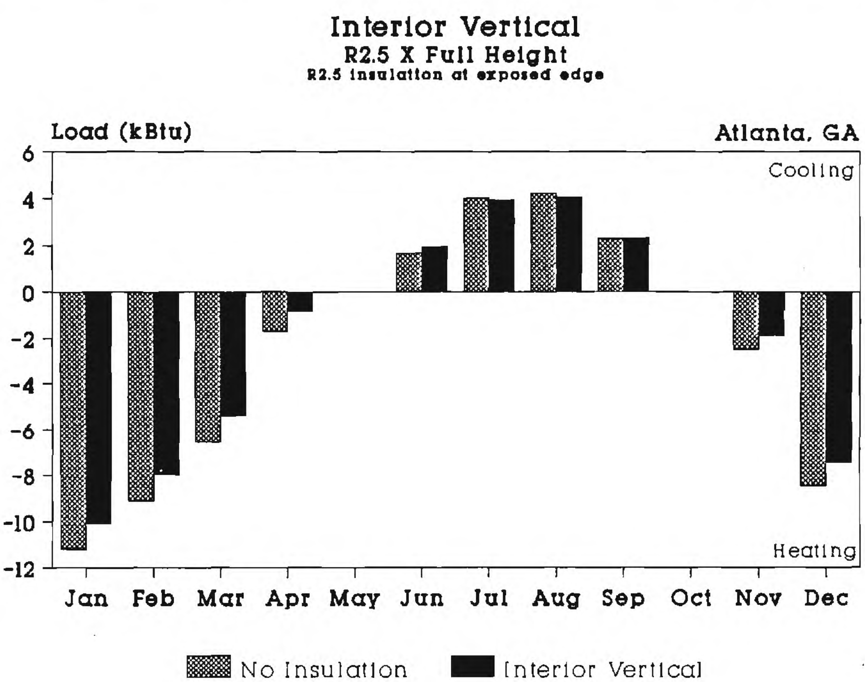


Interior Vertical

R2.5 X Full Height

R2.5 insulation at exposed edge

	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	33,657	5,869	12,326	(77)	10,257	30.5	4,567	44.5	142	1.2
Jan	10,097	1,113	0	0	2,203	21.8	990	45.0	0	0.0
Feb	7,964	1,139	0	0	2,275	28.6	1,038	45.6	0	0.0
Mar	5,381	1,169	0	0	2,520	46.8	1,266	50.2	0	0.0
Apr	834	871	0	0	1,865	0.0	1,127	60.5	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	1,960	(262)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,947	73	0	0.0	0	0.0	21	0.5
Aug	0	0	4,086	120	0	0.0	0	0.0	109	2.7
Sep	0	0	2,329	(6)	0	0.0	0	0.0	12	0.5
Oct	0	0	3	(3)	0	0.0	0	0.0	0	0.0
Nov	1,913	591	0	0	263	13.8	(24)	-9.2	0	0.0
Dec	7,467	987	0	0	1,131	15.1	169	14.9	0	0.0

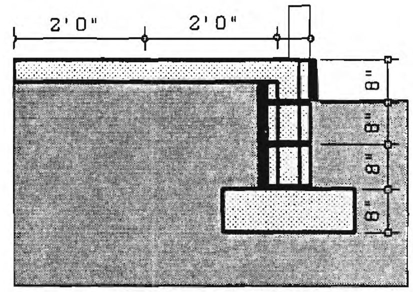


Atlanta, GA

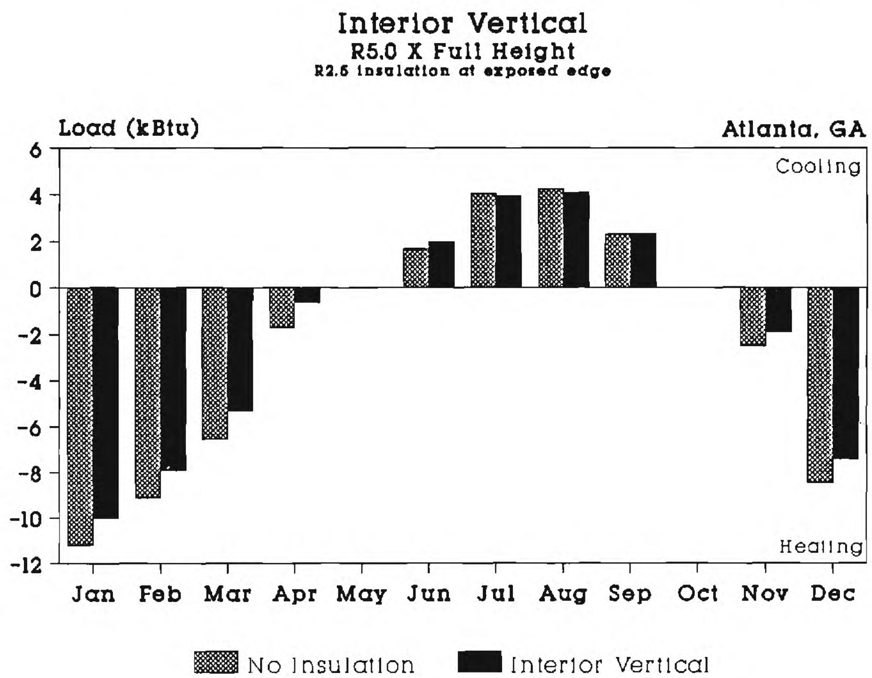
Interior Vertical

R5.0 X Full Height

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	33,171	6,355	12,333	(85)	9,498	28.6	3,766	39.6	141	1.1
Jan	10,034	1,177	0	0	2,139	21.3	875	40.9	0	0.0
Feb	7,899	1,204	0	0	2,210	28.0	921	41.7	0	0.0
Mar	5,313	1,237	0	0	2,451	46.1	1,142	46.6	0	0.0
Apr	623	1,082	0	0	1,366	0.0	798	58.4	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	1,983	(284)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,944	76	0	0.0	0	0.0	22	0.5
Aug	0	0	4,077	130	0	0.0	0	0.0	105	2.6
Sep	0	0	2,326	(3)	0	0.0	0	0.0	14	0.6
Oct	0	0	3	(3)	0	0.0	0	0.0	0	0.0
Nov	1,887	616	0	0	251	13.3	(47)	-18.7	0	0.0
Dec	7,415	1,039	0	0	1,082	14.6	76	7.0	0	0.0

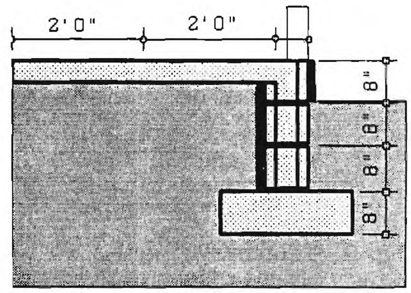


Atlanta, GA

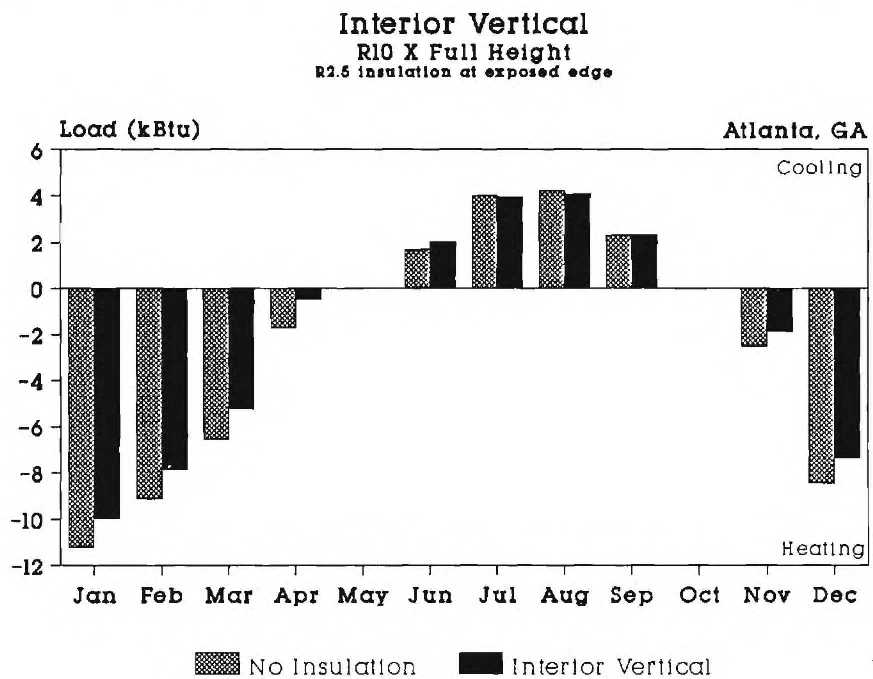
Interior Vertical

R10 X Full Height

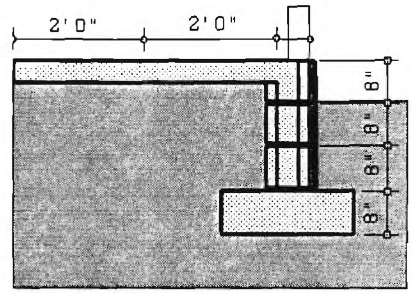
R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	32,826	6,700	12,347	(98)	9,002	27.4	3,194	35.5	141	1.1
Jan	9,981	1,229	0	0	2,087	20.9	778	37.3	0	0.0
Feb	7,845	1,258	0	0	2,156	27.5	822	38.1	0	0.0
Mar	5,258	1,292	0	0	2,397	45.6	1,041	43.5	0	0.0
Apr	499	1,206	0	0	1,078	0.0	606	56.2	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	2,006	(307)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,944	76	0	0.0	0	0.0	23	0.6
Aug	0	0	4,070	136	0	0.0	0	0.0	104	2.6
Sep	0	0	2,324	(0)	0	0.0	0	0.0	14	0.6
Oct	0	0	3	(3)	0	0.0	0	0.0	0	0.0
Nov	1,868	635	0	0	241	12.9	(55)	-22.8	0	0.0
Dec	7,374	1,080	0	0	1,043	14.1	1	0.1	0	0.0



Atlanta, GA

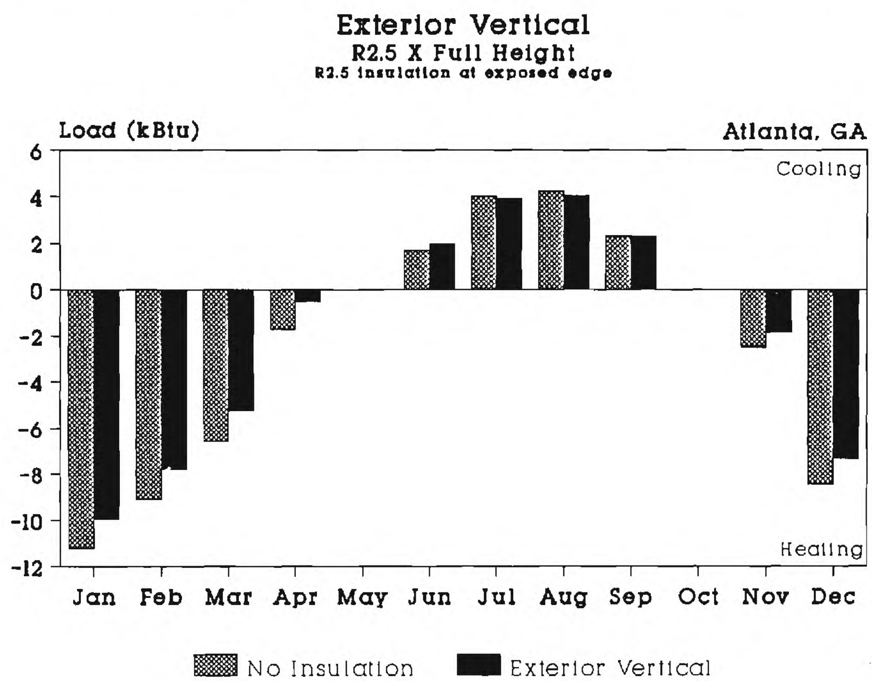


Exterior Vertical

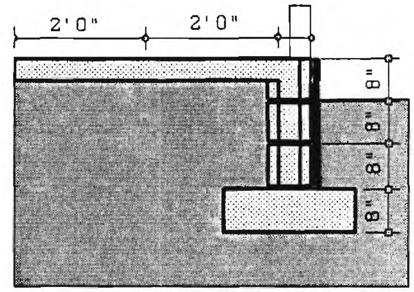
R2.5 X Full Height

R2.5 insulation at exposed edge

	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	32,661	6,864	12,238	10	8,840	27.1	5,781	65.4	64	0.5
Jan	9,949	1,262	0	0	2,054	20.6	1,373	66.8	0	0.0
Feb	7,812	1,291	0	0	2,123	27.2	1,422	67.0	0	0.0
Mar	5,232	1,318	0	0	2,371	45.3	1,632	68.9	0	0.0
Apr	502	1,203	0	0	1,081	0.0	790	73.1	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	1,970	(272)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,916	105	0	0.0	0	0.0	5	0.1
Aug	0	0	4,043	164	0	0.0	0	0.0	56	1.4
Sep	0	0	2,307	17	0	0.0	0	0.0	3	0.1
Oct	0	0	3	(3)	0	0.0	0	0.0	0	0.0
Nov	1,838	665	0	0	215	11.7	67	31.3	0	0.0
Dec	7,328	1,127	0	0	996	13.6	496	49.7	0	0.0



Atlanta, GA

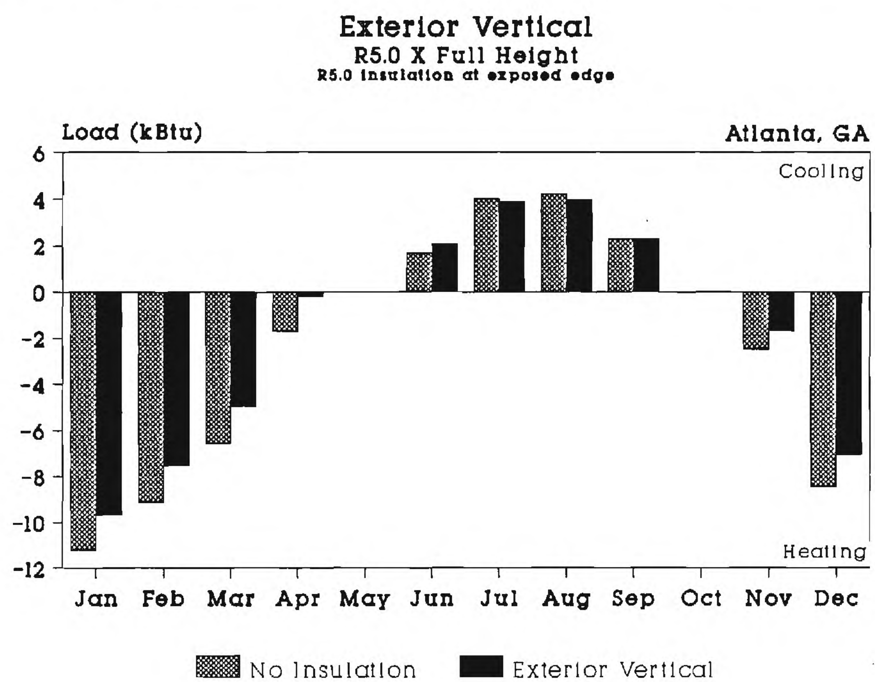


Exterior Vertical

R5.0 X Full Height

R5.0 insulation at exposed edge

	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	31,073	8,453	12,316	(68)	6,925	22.3	4,571	66.0	26	0.2
Jan	9,665	1,545	0	0	1,770	18.3	1,204	68.0	0	0.0
Feb	7,521	1,582	0	0	1,832	24.4	1,246	68.0	0	0.0
Mar	4,934	1,616	0	0	2,074	42.0	1,452	70.0	0	0.0
Apr	188	1,517	0	0	356	0.0	257	72.1	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	2,087	(389)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,909	112	0	0.0	0	0.0	0	0.0
Aug	0	0	4,013	194	0	0.0	0	0.0	25	0.6
Sep	0	0	2,304	19	0	0.0	0	0.0	1	0.0
Oct	0	0	3	(3)	0	0.0	0	0.0	0	0.0
Nov	1,690	813	0	0	135	8.0	41	30.1	0	0.0
Dec	7,075	1,380	0	0	758	10.7	372	49.1	0	0.0

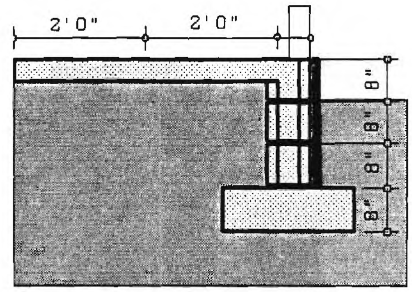


Atlanta, GA

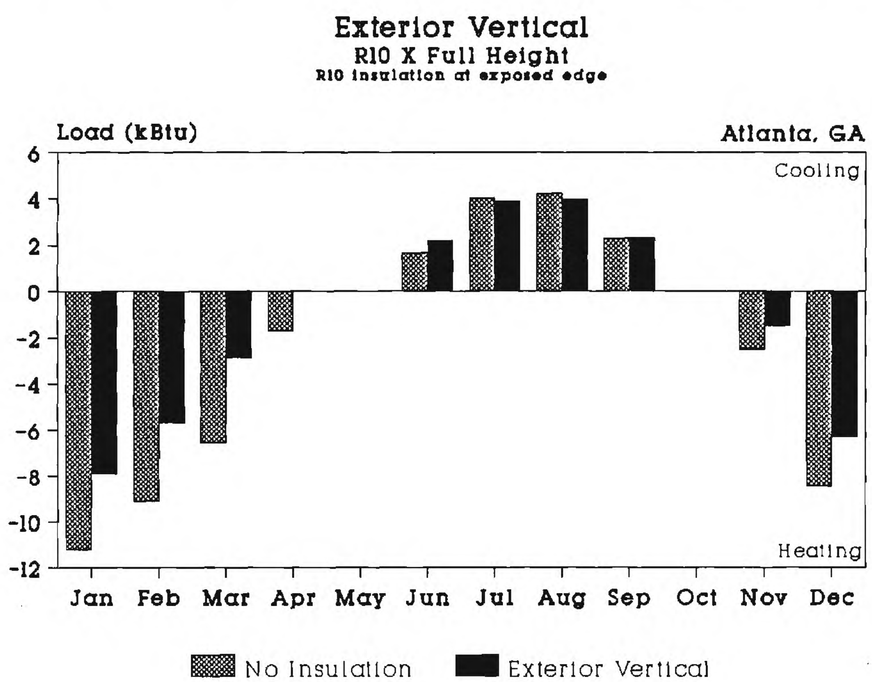
Exterior Vertical

R10 X Full Height

R10 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	24,919	9,607	12,393	(145)	5,720	23.6	3,844	67.2	7	0.1
Jan	9,430	1,780	0	0	1,535	19.4	1,064	69.3	0	0.0
Feb	7,278	1,824	0	0	1,590	27.9	1,102	69.3	0	0.0
Mar	4,683	1,867	0	0	1,820	63.6	1,296	71.2	0	0.0
Apr	93	1,612	0	0	139	0.0	97	69.7	0	0.0
May	0	0	0	0	0	0.0	0	0.0	0	0.0
Jun	0	0	2,197	(498)	0	0.0	0	0.0	0	0.0
Jul	0	0	3,904	117	0	0.0	0	0.0	0	0.0
Aug	0	0	3,988	218	0	0.0	0	0.0	6	0.2
Sep	0	0	2,301	23	0	0.0	0	0.0	0	0.0
Oct	0	0	4	(4)	0	0.0	0	0.0	0	0.0
Nov	1,569	934	0	0	73	4.9	20	27.8	0	0.0
Dec	6,866	1,588	0	0	563	8.9	265	47.0	0	0.0

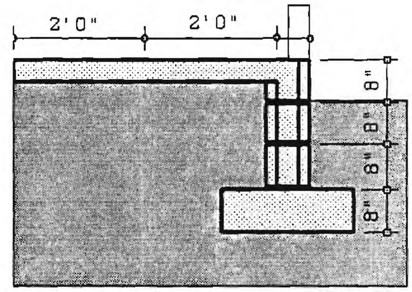


Albany, GA

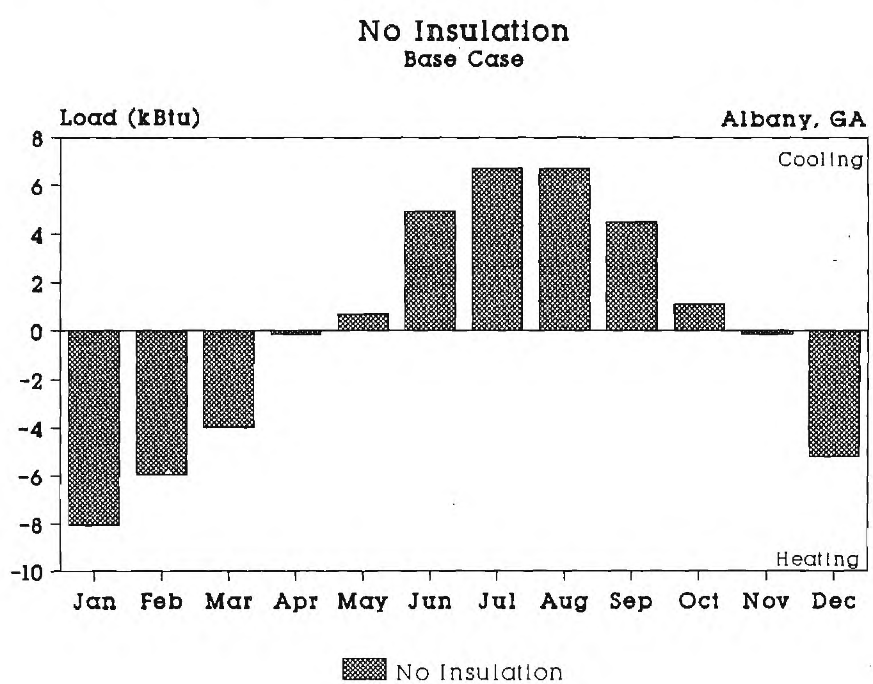
No Insulation

Base Case

8" exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	23,491	0	24,688	0	12,525	53.3	6,737	53.8	3,150	12.8
Jan	8,063	0	0	0	3,301	40.9	1,809	54.8	0	0.0
Feb	5,952	0	0	0	3,331	56.0	1,880	56.4	0	0.0
Mar	3,994	0	0	0	3,358	84.1	1,974	58.8	0	0.0
Apr	158	0	0	0	280	0.0	177	63.1	0	0.0
May	0	0	724	0	0	0.0	0	0.0	0	0.0
Jun	0	0	4,931	0	0	0.0	0	0.0	235	4.8
Jul	0	0	6,707	0	0	0.0	0	0.0	1,020	15.2
Aug	0	0	6,713	0	0	0.0	0	0.0	1,267	18.9
Sep	0	0	4,505	0	0	0.0	0	0.0	609	13.5
Oct	0	0	1,108	0	0	0.0	0	0.0	18	1.6
Nov	136	0	0	0	114	83.8	22	19.4	0	0.0
Dec	5,187	0	0	0	2,141	41.3	875	40.9	0	0.0

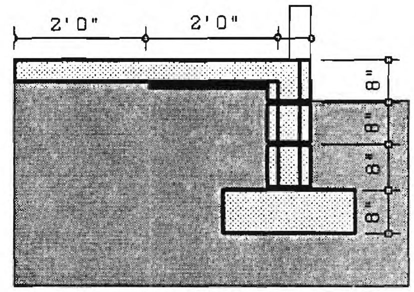


Albany, GA

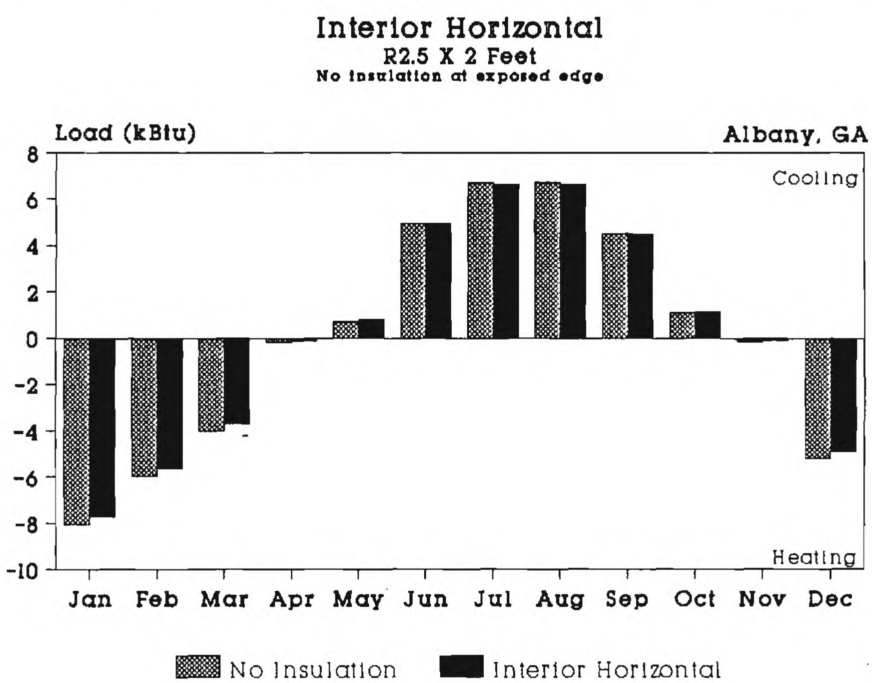
Interior Horizontal

R2.5 X 2 Feet

No insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	22,181	1,310	24,678	10	11,177	50.4	4,946	44.2	2,807	11.4
Jan	7,734	329	0	0	2,972	38.4	1,347	45.3	0	0.0
Feb	5,634	318	0	0	3,014	53.5	1,434	47.6	0	0.0
Mar	3,706	288	0	0	3,070	82.8	1,563	50.9	0	0.0
Apr	111	48	0	0	178	0.0	100	56.2	0	0.0
May	0	0	839	(115)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,937	(5)	0	0.0	0	0.0	234	4.7
Jul	0	0	6,633	74	0	0.0	0	0.0	895	13.5
Aug	0	0	6,631	82	0	0.0	0	0.0	1,118	16.9
Sep	0	0	4,472	33	0	0.0	0	0.0	542	12.1
Oct	0	0	1,166	(58)	0	0.0	0	0.0	19	1.7
Nov	86	51	0	0	74	85.9	1	1.0	0	0.0
Dec	4,911	276	0	0	1,869	38.1	501	26.8	0	0.0

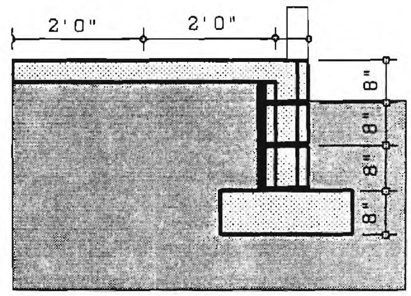


Albany, GA

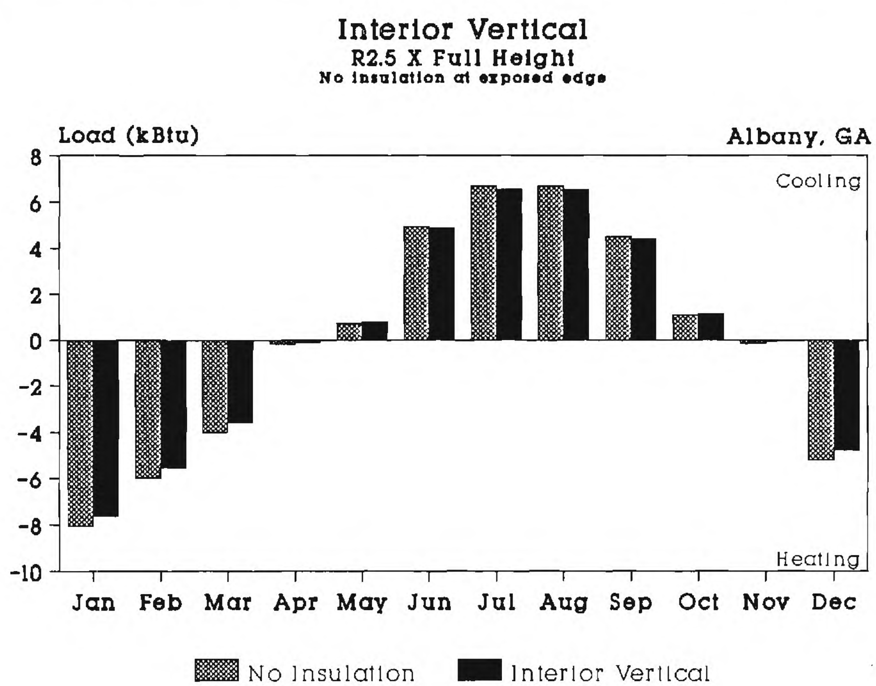
Interior Vertical

R2.5 X Full Height

No insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	21,699	1,792	24,345	343	10,749	49.5	4,311	40.1	2,509	10.3
Jan	7,621	442	0	0	2,859	37.5	1,172	41.0	0	0.0
Feb	5,526	427	0	0	2,904	52.6	1,267	43.6	0	0.0
Mar	3,607	387	0	0	2,971	82.4	1,417	47.7	0	0.0
Apr	108	51	0	0	175	0.0	98	55.8	0	0.0
May	0	0	797	(73)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,871	60	0	0.0	0	0.0	177	3.6
Jul	0	0	6,551	156	0	0.0	0	0.0	794	12.1
Aug	0	0	6,550	163	0	0.0	0	0.0	1,029	15.7
Sep	0	0	4,422	83	0	0.0	0	0.0	493	11.1
Oct	0	0	1,153	(45)	0	0.0	0	0.0	15	1.3
Nov	46	91	0	0	47	0.0	(2)	-4.8	0	0.0
Dec	4,792	395	0	0	1,793	37.4	360	20.1	0	0.0

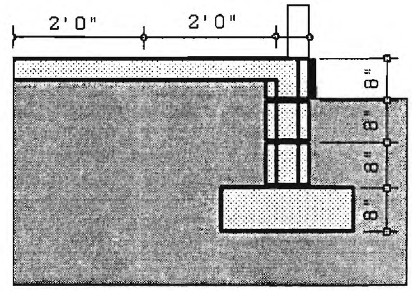


Albany, GA

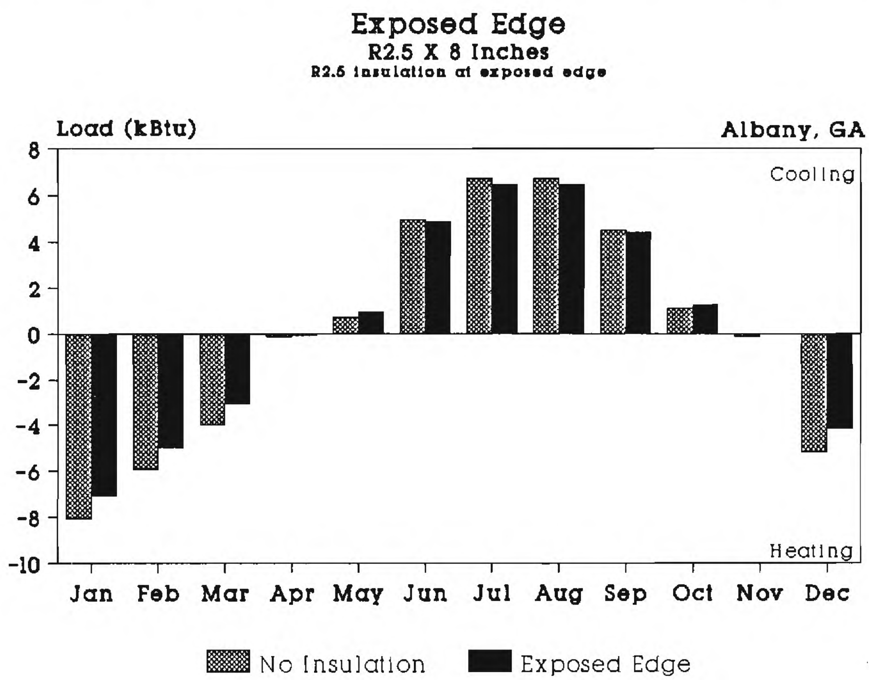
Exposed Edge

R2.5 X 8 Inches

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	(%Tot)	Slab Edge Heat Loss (kBtu)	(%Slb)	Slab Cooling Contribution (kBtu)	(%Tot)
Ann	19,375	4,116	24,401	287	8,483	43.8	4,458	52.6	1,971	8.1
Jan	7,070	993	0	0	2,309	32.7	1,218	52.8	0	0.0
Feb	4,981	971	0	0	2,360	47.4	1,291	54.7	0	0.0
Mar	3,082	912	0	0	2,446	79.4	1,453	59.4	0	0.0
Apr	67	92	0	0	83	0.0	51	61.5	0	0.0
May	0	0	976	(252)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,856	75	0	0.0	0	0.0	64	1.3
Jul	0	0	6,432	275	0	0.0	0	0.0	578	9.0
Aug	0	0	6,443	270	0	0.0	0	0.0	845	13.1
Sep	0	0	4,414	91	0	0.0	0	0.0	464	10.5
Oct	0	0	1,280	(172)	0	0.0	0	0.0	20	1.6
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	4,176	1,012	0	0	1,285	30.8	444	34.6	0	0.0

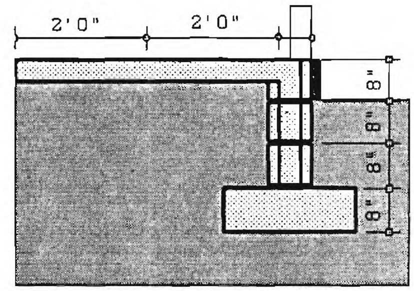


Albany, GA

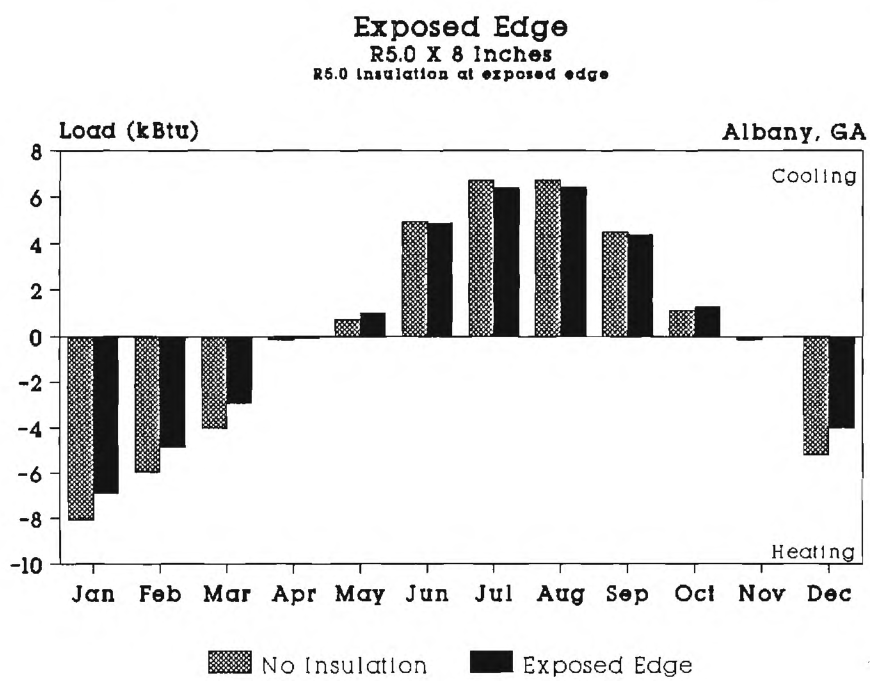
Exposed Edge

R5.0 X 8 Inches

R5.0 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	18,740	4,752	24,412	276	7,878	42.0	3,888	49.4	1,846	7.6
Jan	6,915	1,148	0	0	2,154	31.2	1,067	49.5	0	0.0
Feb	4,829	1,123	0	0	2,208	45.7	1,145	51.9	0	0.0
Mar	2,935	1,059	0	0	2,299	78.3	1,313	57.1	0	0.0
Apr	64	94	0	0	80	0.0	48	60.7	0	0.0
May	0	0	1,029	(305)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,857	75	0	0.0	0	0.0	54	1.1
Jul	0	0	6,402	305	0	0.0	0	0.0	527	8.2
Aug	0	0	6,410	303	0	0.0	0	0.0	794	12.4
Sep	0	0	4,404	101	0	0.0	0	0.0	450	10.2
Oct	0	0	1,309	(201)	0	0.0	0	0.0	21	1.6
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,996	1,191	0	0	1,137	28.5	316	27.8	0	0.0

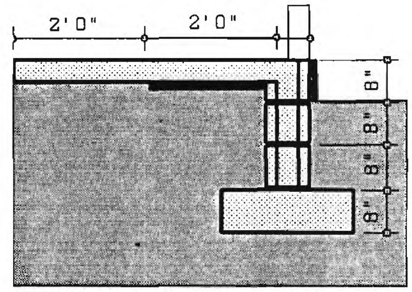


Albany, GA

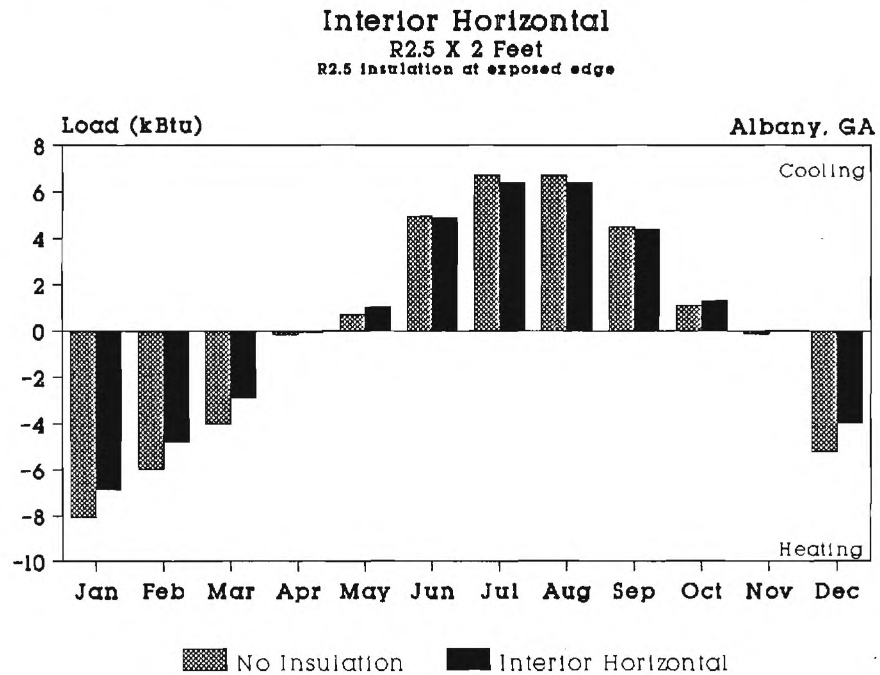
Interior Horizontal

R2.5 X 2 Feet

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	18,582	4,909	24,364	324	7,695	41.4	3,366	43.7	1,692	6.9
Jan	6,867	1,196	0	0	2,107	30.7	928	44.1	0	0.0
Feb	4,782	1,170	0	0	2,162	45.2	1,006	46.5	0	0.0
Mar	2,903	1,091	0	0	2,266	78.1	1,190	52.5	0	0.0
Apr	64	95	0	0	78	0.0	43	55.3	0	0.0
May	0	0	1,053	(329)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,849	82	0	0.0	0	0.0	59	1.2
Jul	0	0	6,378	329	0	0.0	0	0.0	485	7.6
Aug	0	0	6,380	334	0	0.0	0	0.0	722	11.3
Sep	0	0	4,387	118	0	0.0	0	0.0	406	9.3
Oct	0	0	1,317	(210)	0	0.0	0	0.0	20	1.5
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,966	1,221	0	0	1,083	27.3	199	18.4	0	0.0

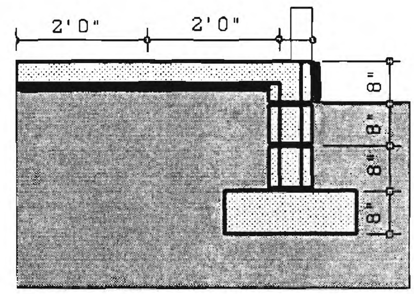


Albany, GA

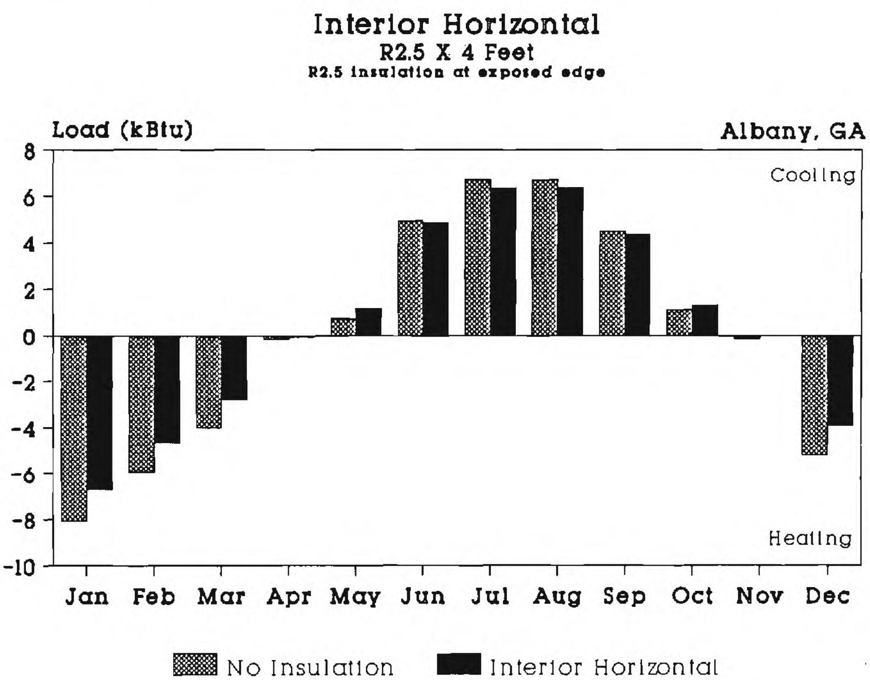
Interior Horizontal

R2.5 X 4 Feet

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	18,133	5,358	24,441	247	7,247	40.0	2,867	39.6	1,609	6.6
Jan	6,702	1,361	0	0	1,941	29.0	759	39.1	0	0.0
Feb	4,652	1,300	0	0	2,031	43.7	866	42.6	0	0.0
Mar	2,789	1,205	0	0	2,153	77.2	1,062	49.3	0	0.0
Apr	61	97	0	0	74	0.0	39	52.7	0	0.0
May	0	0	1,148	(424)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,869	63	0	0.0	0	0.0	55	1.1
Jul	0	0	6,363	344	0	0.0	0	0.0	474	7.5
Aug	0	0	6,353	361	0	0.0	0	0.0	681	10.7
Sep	0	0	4,375	130	0	0.0	0	0.0	380	8.7
Oct	0	0	1,334	(226)	0	0.0	0	0.0	18	1.4
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,929	1,259	0	0	1,047	26.7	141	13.4	0	0.0

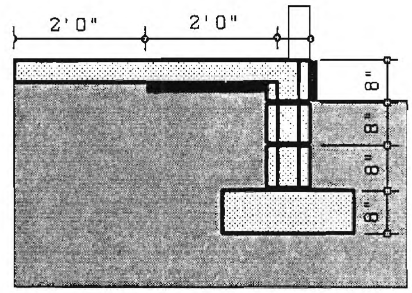


Albany, GA

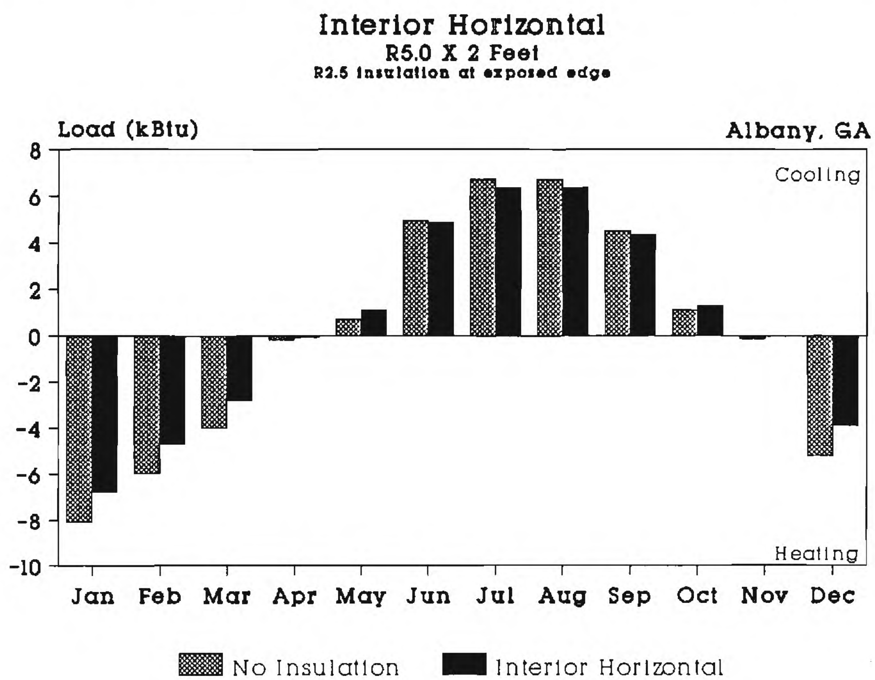
Interior Horizontal

R5.0 X 2 Feet

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	18,260	5,231	24,368	320	7,380	40.4	2,894	39.2	1,609	6.6
Jan	6,777	1,286	0	0	2,015	29.7	795	39.5	0	0.0
Feb	4,695	1,258	0	0	2,074	44.2	876	42.3	0	0.0
Mar	2,821	1,173	0	0	2,184	77.4	1,062	48.6	0	0.0
Apr	62	97	0	0	75	0.0	39	52.2	0	0.0
May	0	0	1,102	(378)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,854	77	0	0.0	0	0.0	61	1.2
Jul	0	0	6,359	348	0	0.0	0	0.0	461	7.3
Aug	0	0	6,352	361	0	0.0	0	0.0	684	10.8
Sep	0	0	4,373	132	0	0.0	0	0.0	383	8.8
Oct	0	0	1,328	(220)	0	0.0	0	0.0	19	1.5
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,906	1,282	0	0	1,031	26.4	121	11.7	0	0.0

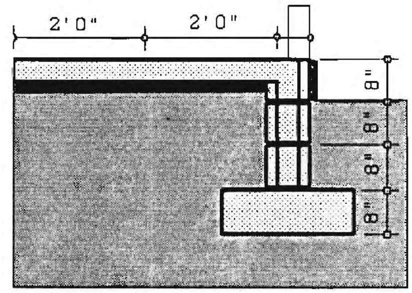


Albany, GA

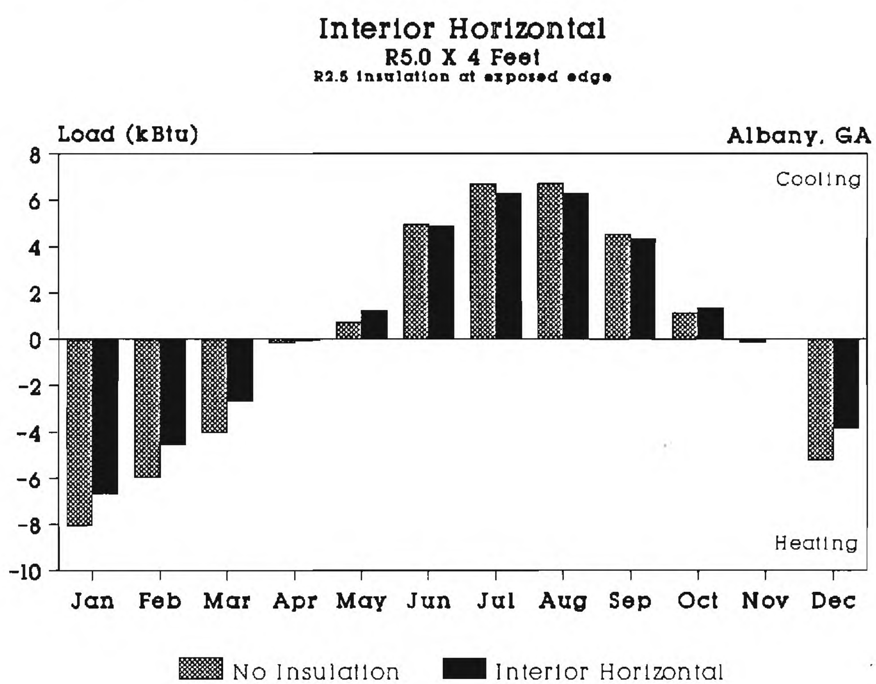
Interior Horizontal

R5.0 X 4 Feet

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	17,785	5,707	24,327	361	6,904	38.8	2,359	34.2	1,425	5.9
Jan	6,667	1,396	0	0	1,905	28.6	671	35.2	0	0.0
Feb	4,554	1,398	0	0	1,934	42.5	721	37.3	0	0.0
Mar	2,676	1,318	0	0	2,040	76.2	906	44.4	0	0.0
Apr	59	99	0	0	71	0.0	34	48.0	0	0.0
May	0	0	1,223	(499)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,856	75	0	0.0	0	0.0	52	1.1
Jul	0	0	6,304	403	0	0.0	0	0.0	431	6.8
Aug	0	0	6,281	432	0	0.0	0	0.0	601	9.6
Sep	0	0	4,328	177	0	0.0	0	0.0	327	7.5
Oct	0	0	1,336	(228)	0	0.0	0	0.0	15	1.1
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,829	1,358	0	0	954	24.9	27	2.9	0	0.0

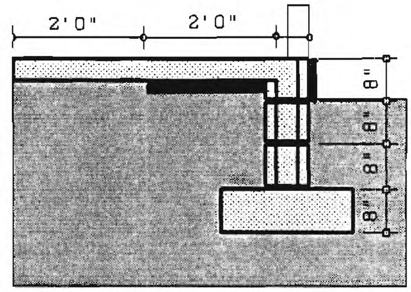


Albany, GA

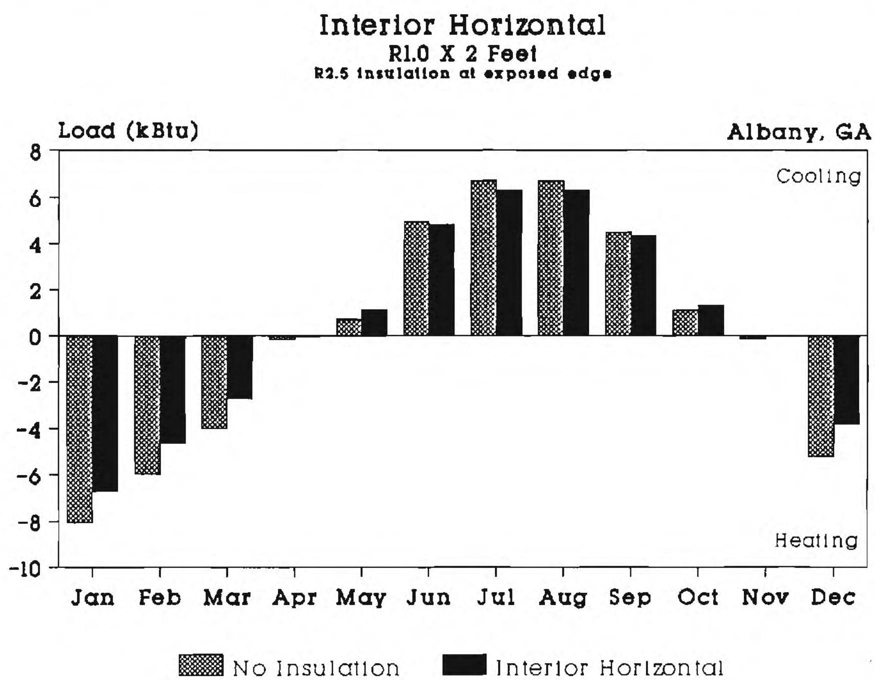
Interior Horizontal

R10 X 2 Feet

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	(%Tot)	Slab Edge Heat Loss (kBtu)	(%Slb)	Slab Cooling Contribution (kBtu)	(%Tot)
Ann	17,971	5,520	24,226	462	7,110	39.6	2,525	35.5	1,469	6.1
Jan	6,731	1,332	0	0	1,969	29.2	719	36.5	0	0.0
Feb	4,621	1,332	0	0	2,000	43.3	774	38.7	0	0.0
Mar	2,741	1,253	0	0	2,105	76.8	952	45.3	0	0.0
Apr	60	98	0	0	73	0.0	36	49.2	0	0.0
May	0	0	1,133	(409)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,834	97	0	0.0	0	0.0	60	1.2
Jul	0	0	6,308	399	0	0.0	0	0.0	423	6.7
Aug	0	0	6,295	419	0	0.0	0	0.0	625	9.9
Sep	0	0	4,334	171	0	0.0	0	0.0	344	7.9
Oct	0	0	1,322	(215)	0	0.0	0	0.0	16	1.2
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,819	1,369	0	0	963	25.2	44	4.6	0	0.0

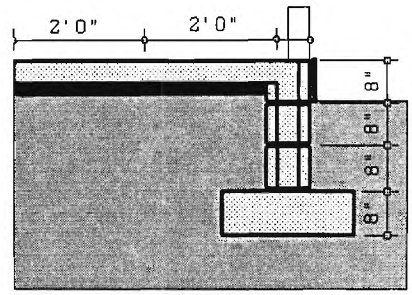


Albany, GA

Interior Horizontal

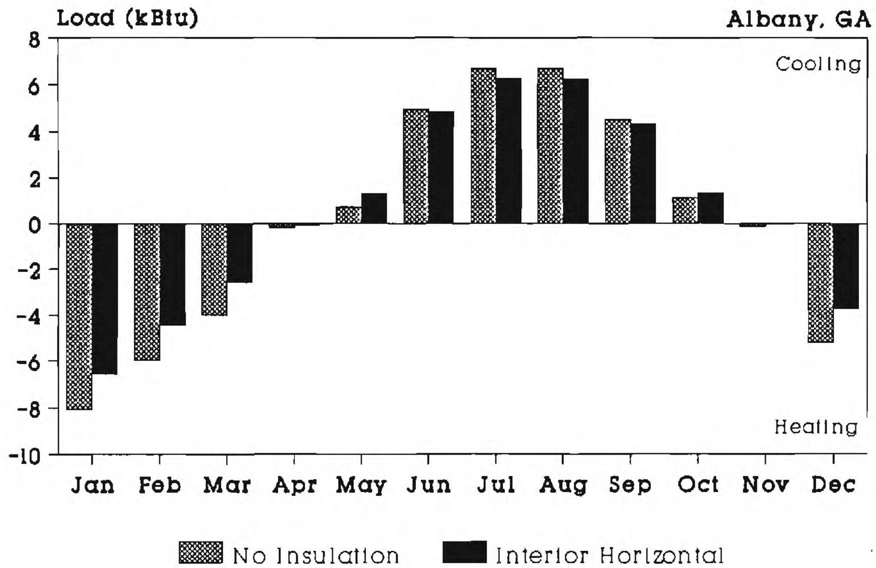
R10 X 4 Feet

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	17,370	6,121	24,345	343	6,490	37.4	1,808	27.9	1,321	5.4
Jan	6,554	1,509	0	0	1,791	27.3	516	28.8	0	0.0
Feb	4,444	1,508	0	0	1,823	41.0	567	31.1	0	0.0
Mar	2,572	1,422	0	0	1,936	75.3	754	39.0	0	0.0
Apr	57	102	0	0	68	0.0	29	43.2	0	0.0
May	0	0	1,290	(567)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,863	68	0	0.0	0	0.0	53	1.1
Jul	0	0	6,280	427	0	0.0	0	0.0	408	6.5
Aug	0	0	6,247	466	0	0.0	0	0.0	550	8.8
Sep	0	0	4,311	194	0	0.0	0	0.0	295	6.8
Oct	0	0	1,353	(245)	0	0.0	0	0.0	16	1.2
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,743	1,444	0	0	872	23.3	(59)	-6.8	0	0.0

Interior Horizontal
R1.0 X 4 Feet
R2.5 insulation at exposed edge

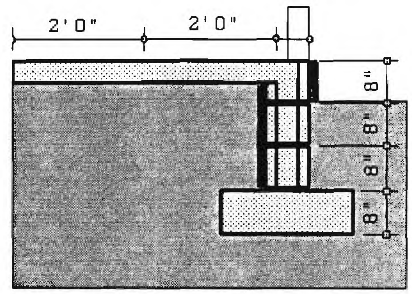


Albany, GA

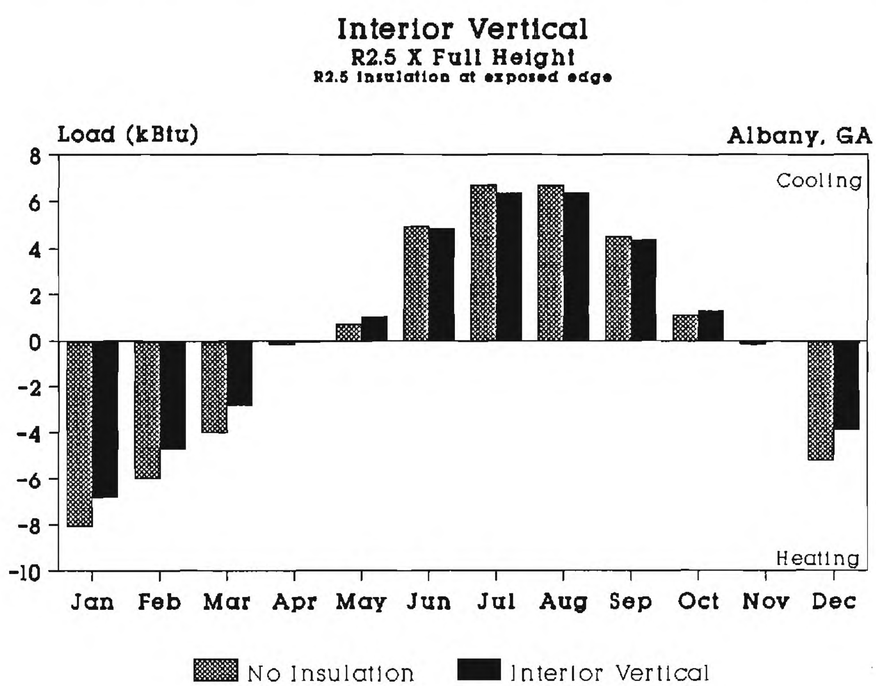
Interior Vertical

R2.5 X Full Height

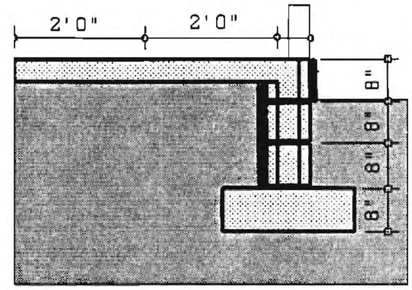
R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	18,339	5,152	24,252	436	7,510	40.9	2,751	36.6	1,665	6.9
Jan	6,810	1,253	0	0	2,051	30.1	757	36.9	0	0.0
Feb	4,725	1,227	0	0	2,105	44.5	843	40.1	0	0.0
Mar	2,844	1,150	0	0	2,208	77.7	1,043	47.2	0	0.0
Apr	63	96	0	0	76	0.0	40	52.8	0	0.0
May	0	0	1,040	(316)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,838	93	0	0.0	0	0.0	59	1.2
Jul	0	0	6,356	351	0	0.0	0	0.0	478	7.5
Aug	0	0	6,352	362	0	0.0	0	0.0	714	11.2
Sep	0	0	4,363	142	0	0.0	0	0.0	396	9.1
Oct	0	0	1,304	(196)	0	0.0	0	0.0	18	1.4
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,897	1,290	0	0	1,070	27.5	68	6.4	0	0.0



Albany, GA

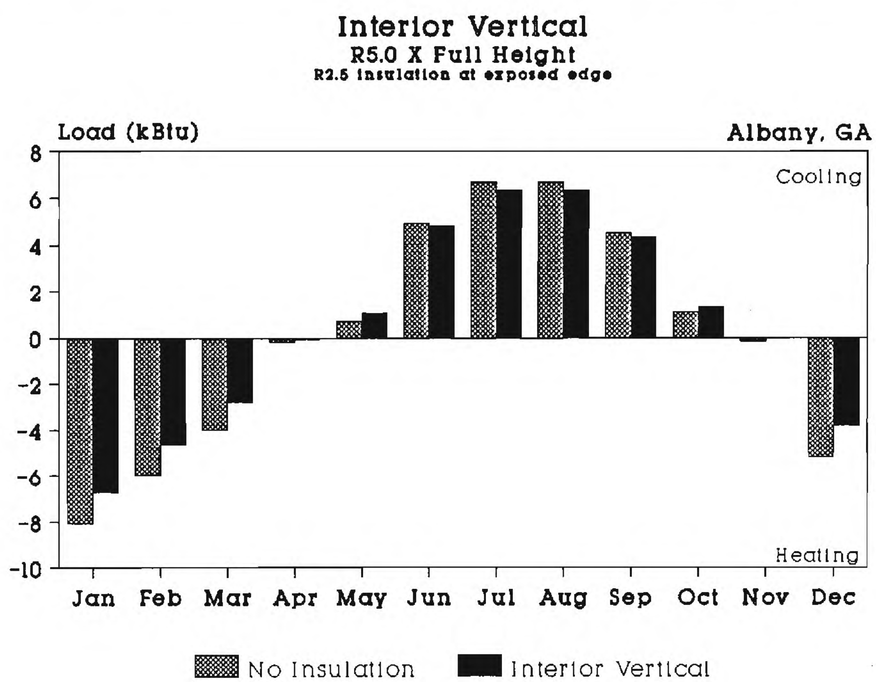


Interior Vertical

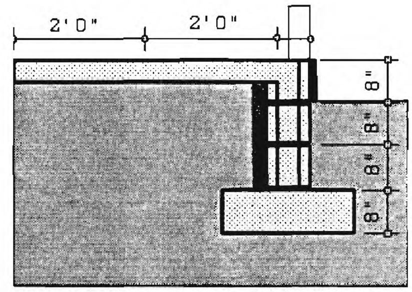
R5.0 X Full Height

R2.5 insulation at exposed edge

	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	18,049	5,443	24,215	473	7,239	40.1	2,271	31.4	1,580	6.5
Jan	6,735	1,328	0	0	1,975	29.3	624	31.6	0	0.0
Feb	4,653	1,299	0	0	2,033	43.7	713	35.1	0	0.0
Mar	2,776	1,218	0	0	2,139	77.1	925	43.2	0	0.0
Apr	61	97	0	0	74	0.0	37	49.5	0	0.0
May	0	0	1,061	(337)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,834	97	0	0.0	0	0.0	58	1.2
Jul	0	0	6,336	371	0	0.0	0	0.0	452	7.1
Aug	0	0	6,326	387	0	0.0	0	0.0	677	10.7
Sep	0	0	4,348	157	0	0.0	0	0.0	375	8.6
Oct	0	0	1,310	(203)	0	0.0	0	0.0	17	1.3
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,823	1,364	0	0	1,018	26.6	(28)	-2.8	0	0.0



Albany, GA



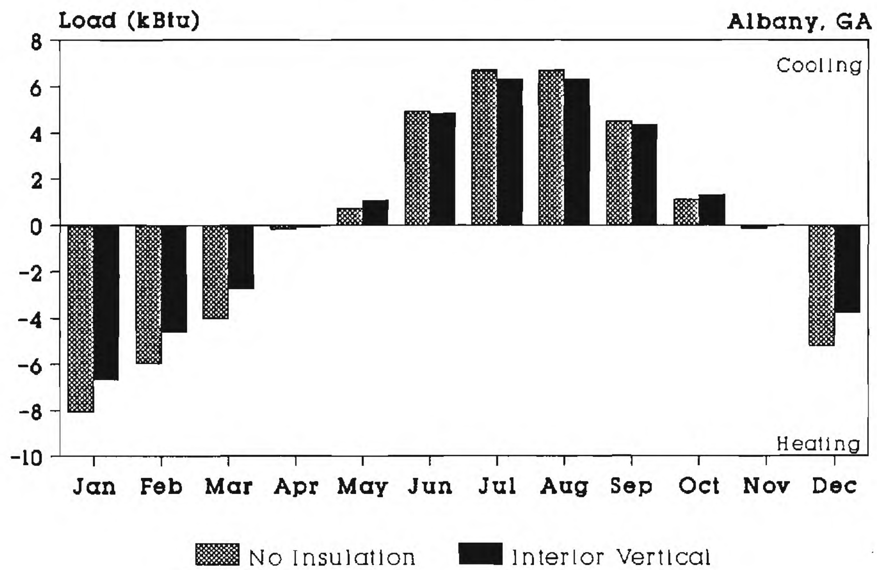
Interior Vertical

R10 X Full Height

R2.5 insulation at exposed edge

	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	17,818	5,673	24,187	501	7,024	39.4	1,889	26.9	1,517	6.3
Jan	6,676	1,386	0	0	1,916	28.7	517	27.0	0	0.0
Feb	4,595	1,357	0	0	1,975	43.0	608	30.8	0	0.0
Mar	2,721	1,272	0	0	2,085	76.6	829	39.8	0	0.0
Apr	60	98	0	0	73	0.0	34	46.7	0	0.0
May	0	0	1,079	(355)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,831	100	0	0.0	0	0.0	59	1.2
Jul	0	0	6,319	388	0	0.0	0	0.0	434	6.9
Aug	0	0	6,305	408	0	0.0	0	0.0	647	10.3
Sep	0	0	4,336	169	0	0.0	0	0.0	360	8.3
Oct	0	0	1,316	(208)	0	0.0	0	0.0	17	1.3
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,765	1,422	0	0	976	25.9	(99)	-10.1	0	0.0

Interior Vertical
R10 X Full Height
R2.5 insulation at exposed edge

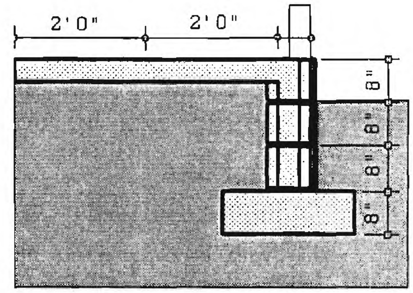


Albany, GA

Exterior Vertical

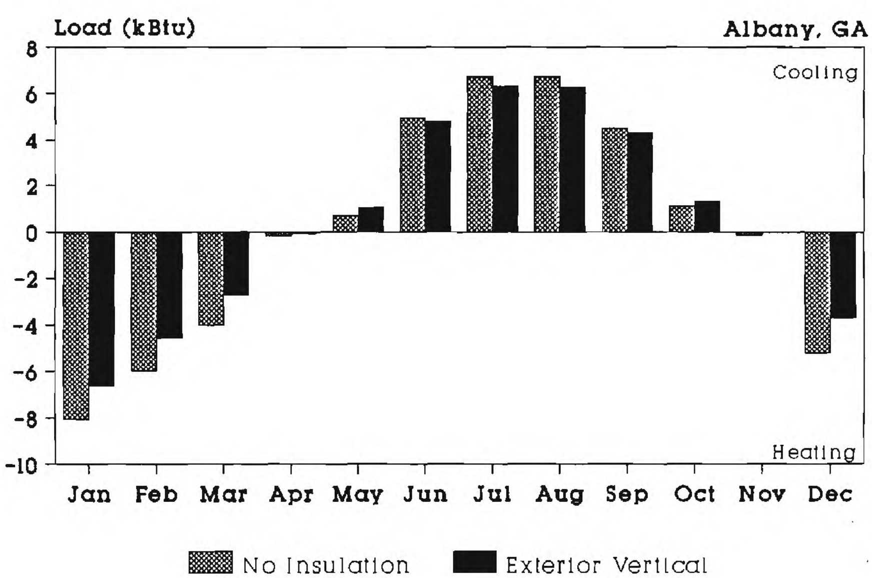
R2.5 X Full Height

R2.5 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	17,702	5,789	24,027	661	6,912	39.0	4,315	62.4	1,327	5.5
Jan	6,652	1,411	0	0	1,892	28.4	1,188	62.8	0	0.0
Feb	4,570	1,383	0	0	1,949	42.7	1,255	64.4	0	0.0
Mar	2,712	1,281	0	0	2,076	76.6	1,403	67.5	0	0.0
Apr	60	98	0	0	73	0.0	46	63.9	0	0.0
May	0	0	1,048	(324)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,799	132	0	0.0	0	0.0	22	0.5
Jul	0	0	6,285	422	0	0.0	0	0.0	371	5.9
Aug	0	0	6,270	444	0	0.0	0	0.0	591	9.4
Sep	0	0	4,315	190	0	0.0	0	0.0	328	7.6
Oct	0	0	1,312	(204)	0	0.0	0	0.0	15	1.1
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,708	1,480	0	0	922	24.9	423	45.9	0	0.0

Exterior Vertical
R2.5 X Full Height
R2.5 insulation at exposed edge

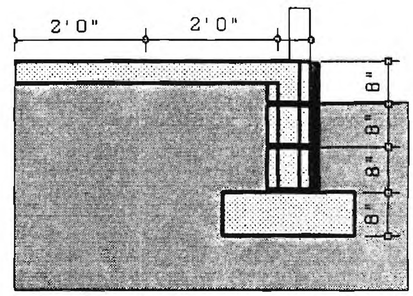


Albany, GA

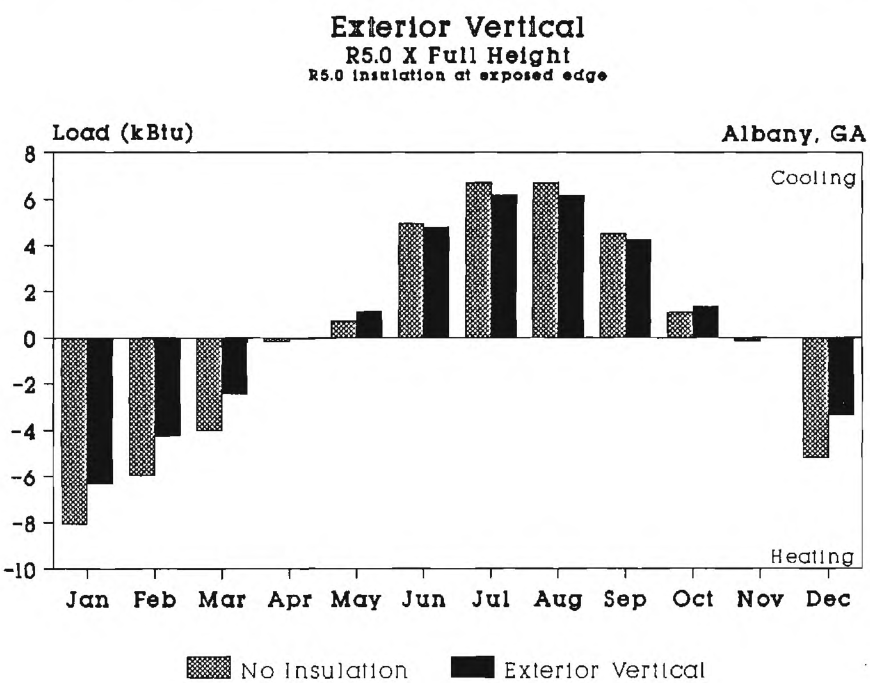
Exterior Vertical

R5.0 X Full Height

R5.0 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	16,412	7,079	23,930	758	5,710	34.8	3,613	63.3	987	4.1
Jan	6,331	1,732	0	0	1,572	24.8	993	63.2	0	0.0
Feb	4,256	1,697	0	0	1,635	38.4	1,062	65.0	0	0.0
Mar	2,421	1,573	0	0	1,783	73.7	1,217	68.3	0	0.0
Apr	53	106	0	0	65	0.0	42	64.9	0	0.0
May	0	0	1,143	(419)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,784	148	0	0.0	0	0.0	7	0.1
Jul	0	0	6,202	505	0	0.0	0	0.0	252	4.1
Aug	0	0	6,176	537	0	0.0	0	0.0	449	7.3
Sep	0	0	4,270	234	0	0.0	0	0.0	265	6.2
Oct	0	0	1,355	(247)	0	0.0	0	0.0	15	1.1
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,352	1,836	0	0	656	19.6	299	45.6	0	0.0

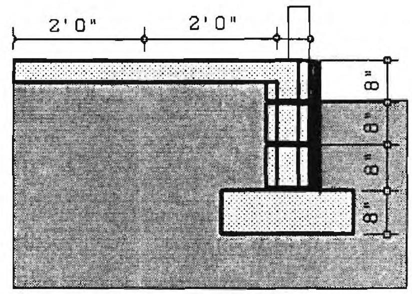


Albany, GA

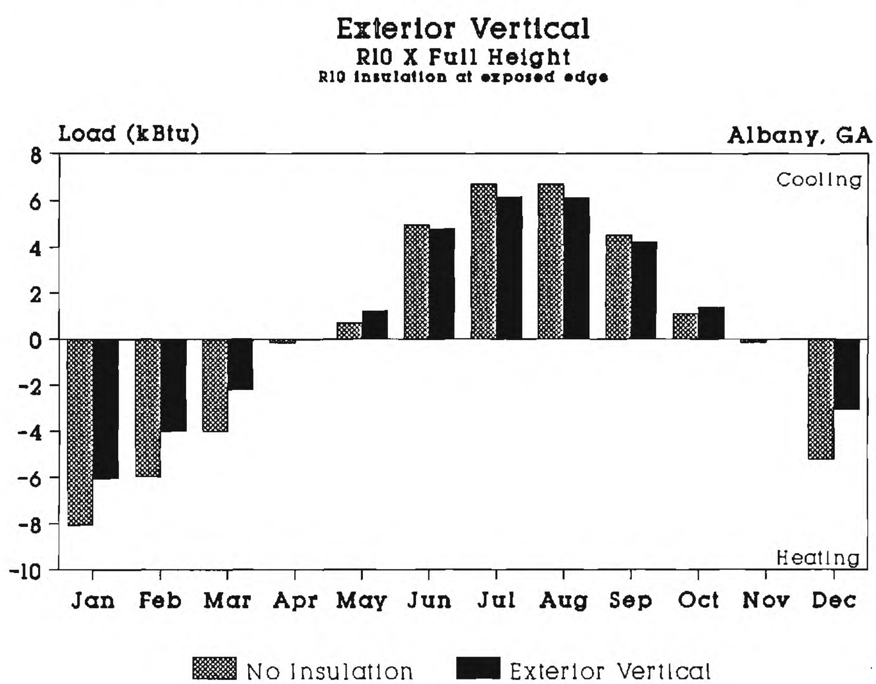
Exterior Vertical

R10 X Full Height

R10 insulation at exposed edge



	Heating Load (kBtu)	Heating Savings (kBtu)	Cooling Load (kBtu)	Cooling Savings (kBtu)	Slab Total Heat Loss (kBtu)	Slab Total Heat Loss (%Tot)	Slab Edge Heat Loss (kBtu)	Slab Edge Heat Loss (%Slb)	Slab Cooling Contribution (kBtu)	Slab Cooling Contribution (%Tot)
Ann	15,345	8,146	23,849	839	4,726	30.8	3,021	63.9	720	3.0
Jan	6,062	2,001	0	0	1,304	21.5	826	63.4	0	0.0
Feb	3,994	1,958	0	0	1,374	34.4	900	65.5	0	0.0
Mar	2,179	1,815	0	0	1,538	70.6	1,063	69.1	0	0.0
Apr	46	112	0	0	58	0.0	38	65.0	0	0.0
May	0	0	1,226	(502)	0	0.0	0	0.0	0	0.0
Jun	0	0	4,772	159	0	0.0	0	0.0	1	0.0
Jul	0	0	6,135	572	0	0.0	0	0.0	158	2.6
Aug	0	0	6,097	616	0	0.0	0	0.0	332	5.4
Sep	0	0	4,232	273	0	0.0	0	0.0	214	5.1
Oct	0	0	1,388	(280)	0	0.0	0	0.0	15	1.1
Nov	0	136	0	0	0	0.0	0	0.0	0	0.0
Dec	3,064	2,123	0	0	453	14.8	194	42.9	0	0.0



Comparison

Comparison

Two simulations were conducted for each location based of the present recommendations for placement of insulation, interior horizontal for two feet of depth and interior vertical both at insulation levels of R 2.5, both without any treatment of the exposed edge. As indicated in Figures 5.3 and 5.4 only negligible reductions in heating loads resulted with the edge condition overwhelming the retardation of any flow through the slab vertically or through the foundation wall horizontally.

Two simulations for each location, one with R 2.5 and one with R 5.0 placement of insulation at the eight inch exposed edge about the perimeter were conducted to evaluate the nature of the thermal bridge from slab to foundation wall. The results shown in Figures 5.5 and 5.6 indicate treatment of the exposed edge above grade proves more effective than the placement of two lineal feet of R 2.5 insulation in the previous cases. No further simulations were considered without the inclusion of a minimal R 2.5 treatment of the exposed edge condition.

Six simulations were conducted for each location modelling three levels of insulation in a horizontal position immediately below the slab from the inside edge of the foundation wall to a point two feet and four feet into the interior. Each case assumes the presence of a minimum of R 2.5 insulation covering the eight inches of exposed edge at the exterior perimeter. A comparison is shown in Figures 5.7 through 5.9. In all cases for Atlanta the annual heating load was reduced and the annual cooling load showed a slight increase. The annual heating loads for Albany were also reduced in all cases, however, unlike Atlanta the annual cooling loads were reduced for all cases. Only small increases in savings were experienced when increasing the same levels of insulation from two feet to four into the interior.

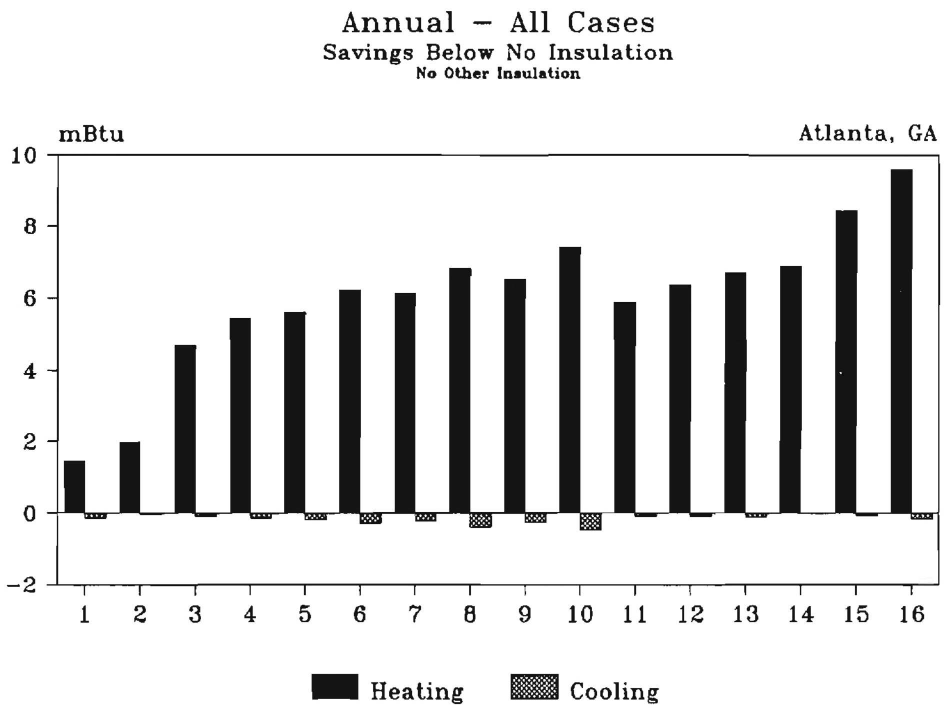
Three simulations were conducted for each location modelling three levels of insulation at the interior face of the foundation wall from the bottom of the slab to the top of the footing. Again each case assumes the presence of a minimum of R 2.5 insulation covering the eight inches of exposed edge at the exterior perimeter. As indicated in Figures 5.11 and 5.12 all three cases prove a savings, but the placement technique is insensitive to increasing levels of insulation.

Expansion of the treatment of the exposed edge condition to include full height placement from top of slab to top of footing proved to be the most effective placement technique. As shown in Figures 5.13 and 5.14, Atlanta experiences six months and Albany four months with heating savings of 1 MBtu or greater. Atlanta experienced only one month with a load increase. Albany experiences two months of load increase which is negated by larger monthly saving during other cooling months.

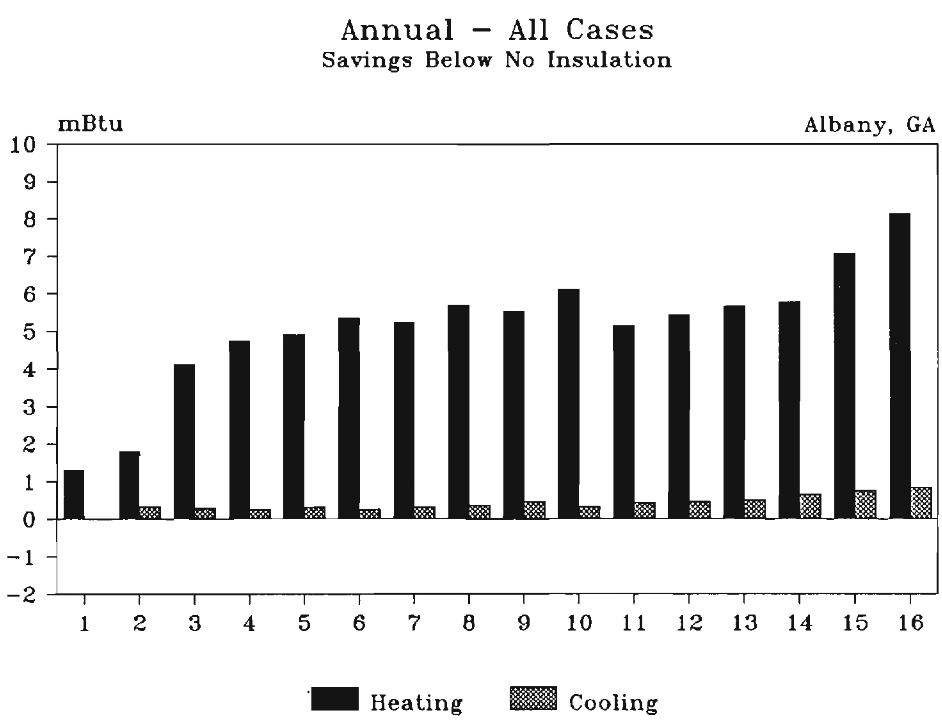
1	Interior Horizontal R 2.5 X 2	(None @ Edge)
2	Interior Horizontal R 2.5 X 2	(None @ Edge)
3	R 2.5 @ Exposed Edge	
4	R 5.0 @ Exposed Edge	
5	Interior Horizontal R 2.5 X 2	(R2.5 @ Edge)
6	Interior Horizontal R 2.5 X 4	(R2.5 @ Edge)
7	Interior Horizontal R 5.0 X 2	(R2.5 @ Edge)
8	Interior Horizontal R 5.0 X 4	(R2.5 @ Edge)
9	Interior Horizontal R10.0 X 2	(R2.5 @ Edge)
10	Interior Horizontal R10.0 X 4	(R2.5 @ Edge)
11	Interior Vertical R 2.5	(R2.5 @ Edge)
12	Interior Vertical R 5.0	(R2.5 @ Edge)
13	Interior Vertical R10.0	(R2.5 @ Edge)
14	Exterior Vertical R 2.5	Full height
15	Exterior Vertical R 5.0	Full height
16	Exterior Vertical R10.0	Full height

Index to Figures 5.1 and 5.2 **Table 5.1**

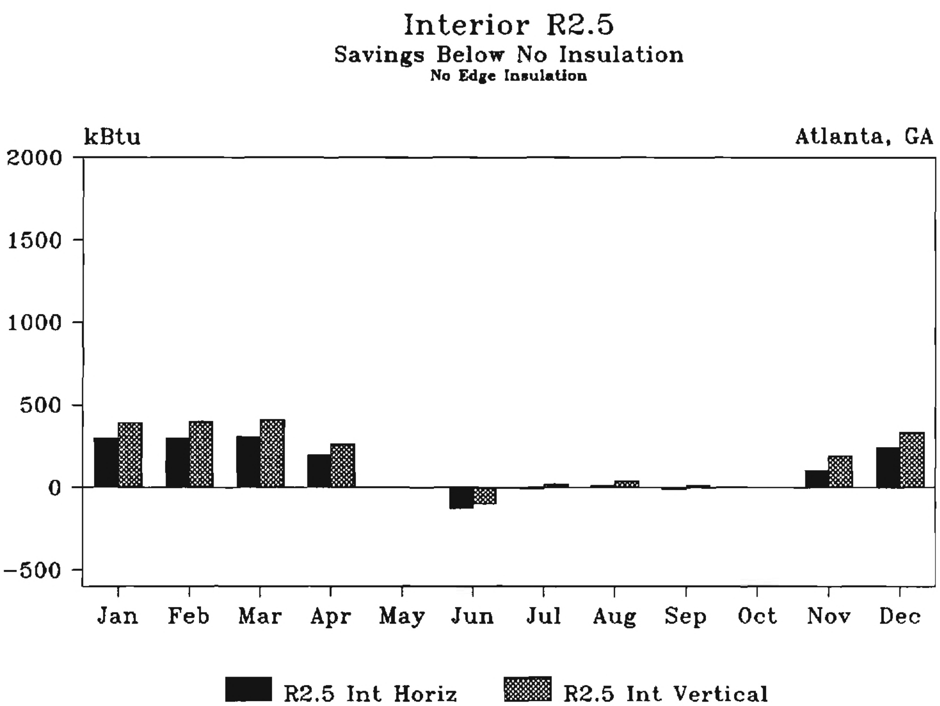
Figures 5.1 and 5.2 compare savings of all cases relative to an uninsulated slab on an annual basis. Table 5.1 provides an index of the placement technique and insulation level. Disregarding the two cases with no edge insulation, annual heating savings range from 4.70 to 9.61 MBtu averaging 6.61 MBtu for Atlanta and from 4.12 to 8.15 MBtu averaging 5.64 MBtu for Albany.



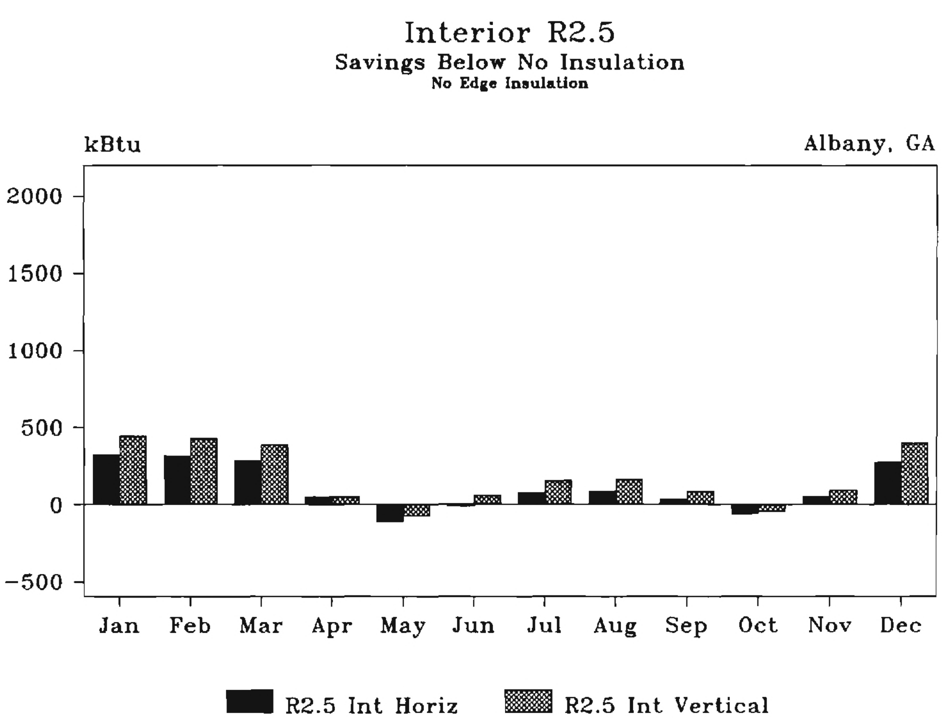
Savings All Cases **Figure 5.1**



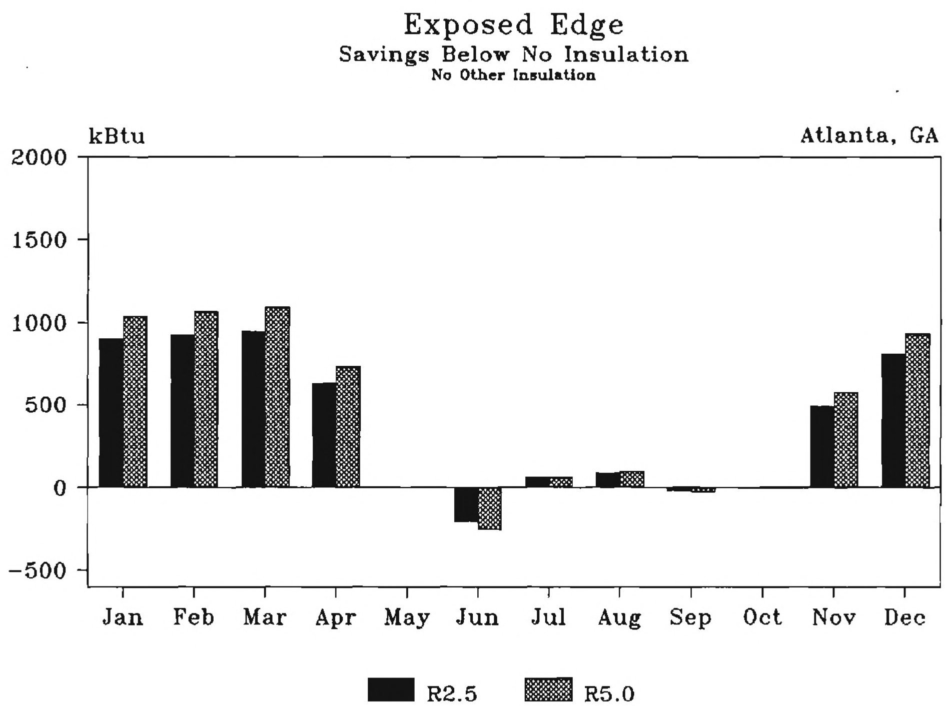
Savings All Cases **Figure 5.2**



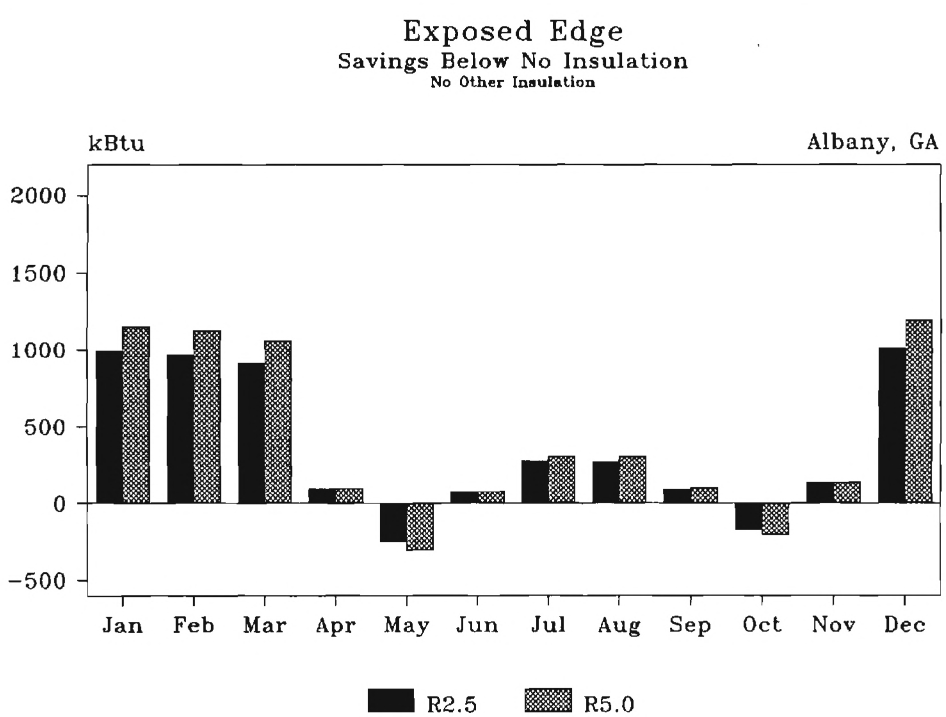
Savings Interior R2.5 **Figure 5.3**



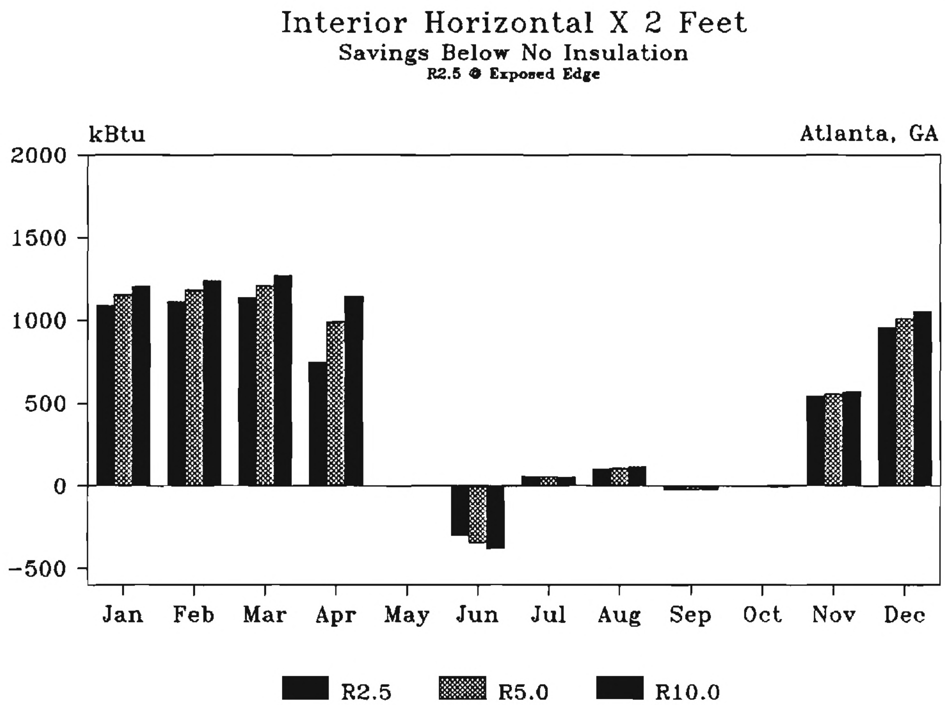
Savings Interior R2.5 **Figure 5.4**



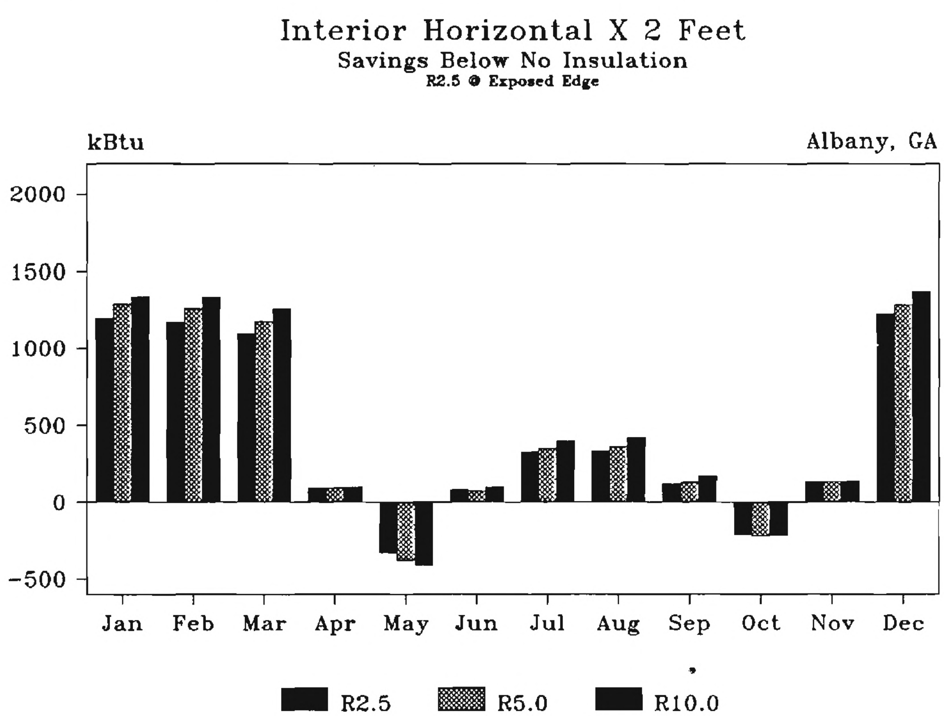
Savings Exposed Edge **Figure 5.5**



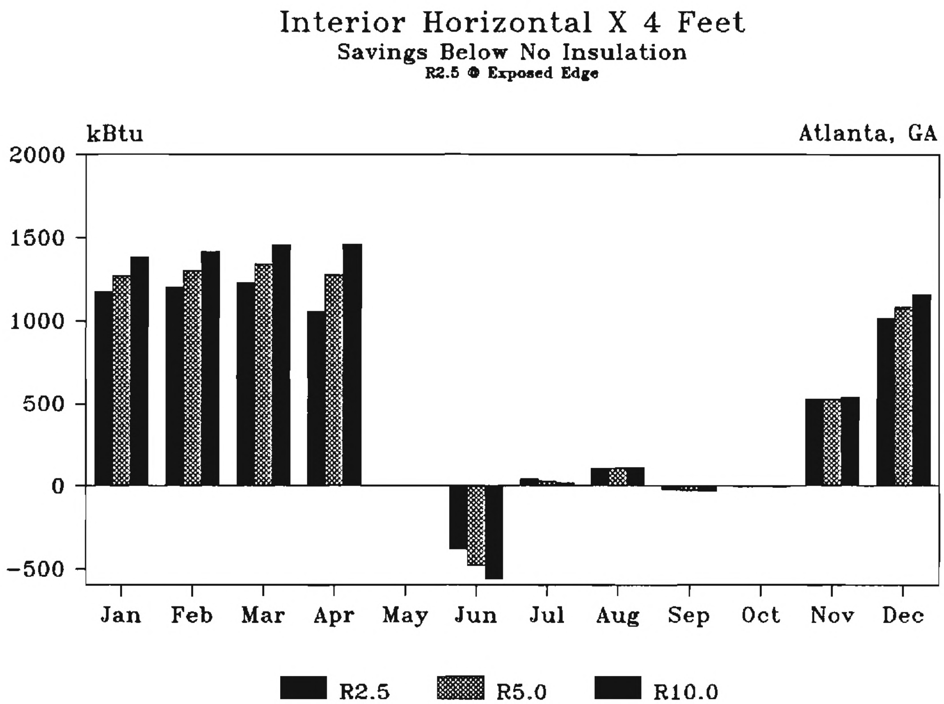
Savings Exposed Edge **Figure 5.6**



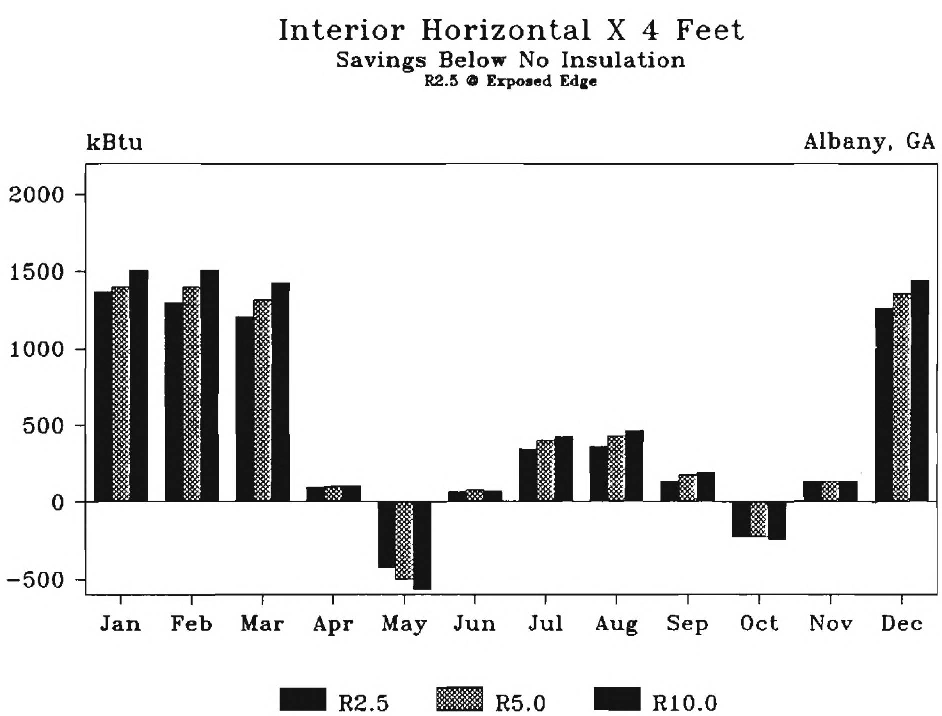
Savings Interior Horizontal **Figure 5.7**



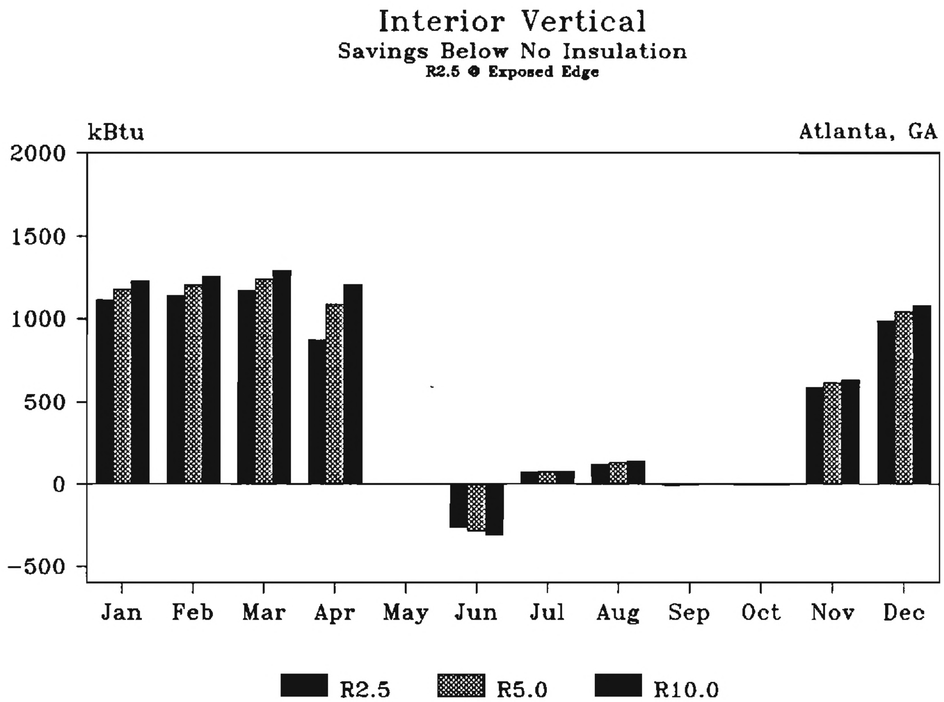
Savings Interior Horizontal **Figure 5.8**



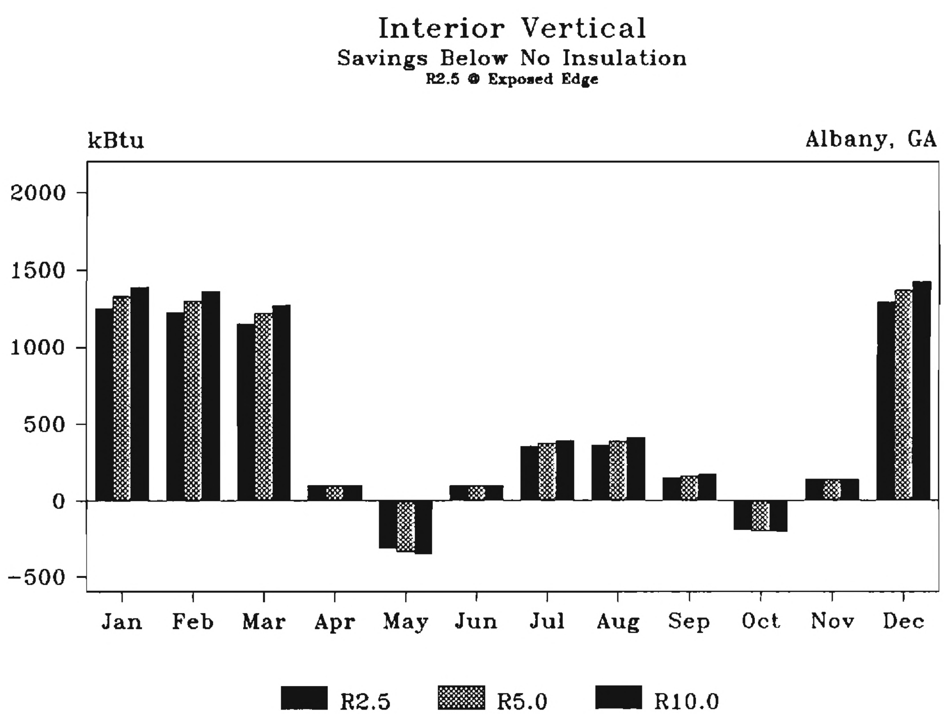
Savings Interior Horizontal **Figure 5.9**



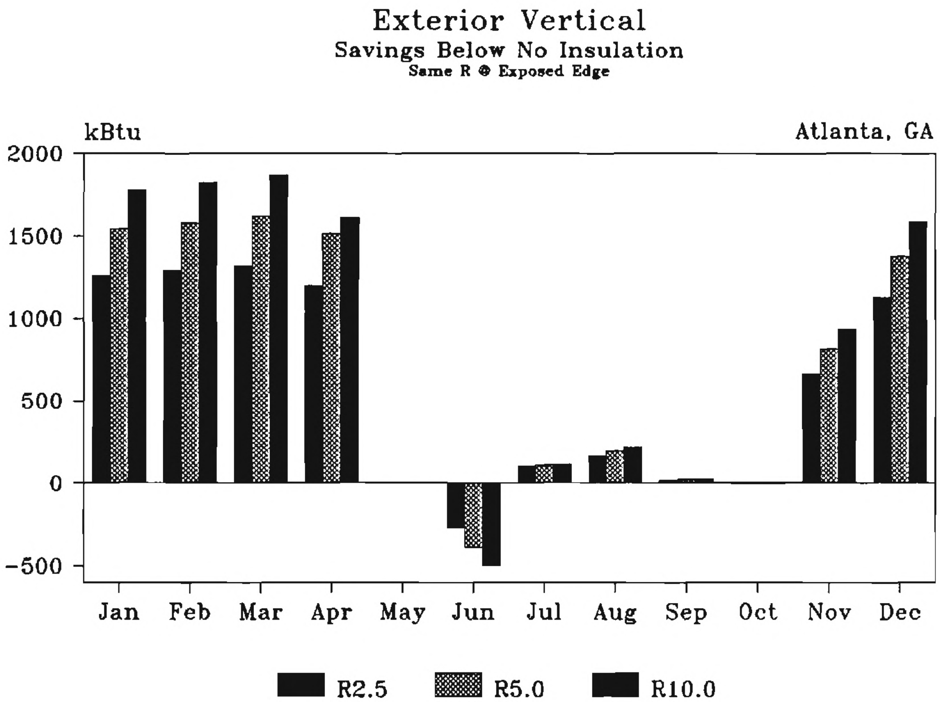
Savings Interior Horizontal **Figure 5.10**



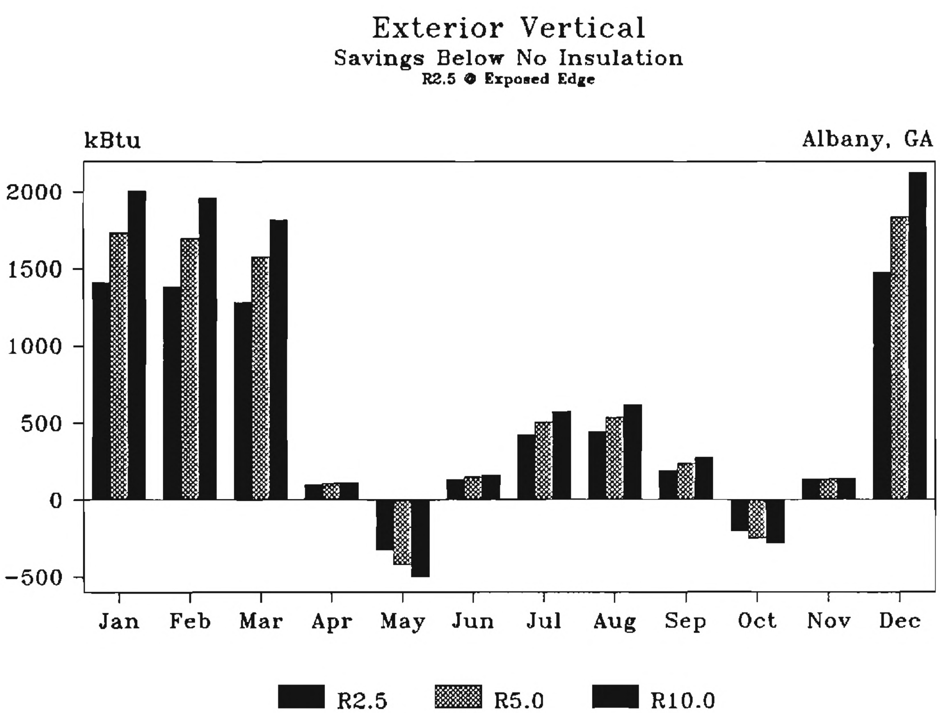
Savings Interior Vertical **Figure 5.11**



Savings Interior Vertical **Figure 5.12**



Savings Exterior Vertical **Figure 5.13**



Savings Exterior Vertical **Figure 5.14**

Design Conditions

Ambient peak design conditions occur on day twenty-seven, January 27th, for Albany and on day thirty-five, February 4th, for Atlanta. A special simulation was preformed for each insulation strategy to determine corresponding peak design heat loss per lineal foot of perimeter. Results are tabulated in Tables 5.2 and 5.3 and indicate a significant difference from the present ASHRAE recommendations of 50, 40, and 30 Btu/foot for uninsulated, R 2.5, and R5.0 insulation, respectfully.

No Insulation		33 Btu/ft
Interior Horizontal R 2.5 X 2	(None @ Edge)	29 Btu/ft
Interior Horizontal R 2.5 X 2	(None @ Edge)	28 Btu/ft
R 2.5 @ Exposed Edge		23 Btu/ft
R 5.0 @ Exposed Edge		21 Btu/ft
Interior Horizontal R 2.5 X 2	(R2.5 @ Edge)	21 Btu/ft
Interior Horizontal R 2.5 X 4	(R2.5 @ Edge)	20 Btu/ft
Interior Horizontal R 5.0 X 2	(R2.5 @ Edge)	21 Btu/ft
Interior Horizontal R 5.0 X 4	(R2.5 @ Edge)	19 Btu/ft
Interior Horizontal R10.0 X 2	(R2.5 @ Edge)	20 Btu/ft
Interior Horizontal R10.0 X 4	(R2.5 @ Edge)	17 Btu/ft
Interior Vertical R 2.5	(R2.5 @ Edge)	21 Btu/ft
Interior Vertical R 5.0	(R2.5 @ Edge)	22 Btu/ft
Interior Vertical R10.0	(R2.5 @ Edge)	20 Btu/ft
Exterior Vertical R 2.5	Full height	20 Btu/ft
Exterior Vertical R 5.0	Full height	18 Btu/ft
Exterior Vertical R10.0	Full height	15 Btu/ft

Atlanta Design Heat Loss **Table 5.2**

No Insulation		29 Btu/ft
Interior Horizontal R 2.5 X 2	(None @ Edge)	26 Btu/ft
Interior Horizontal R 2.5 X 2	(None @ Edge)	26 Btu/ft
R 2.5 @ Exposed Edge		20 Btu/ft
R 5.0 @ Exposed Edge		18 Btu/ft
Interior Horizontal R 2.5 X 2	(R2.5 @ Edge)	19 Btu/ft
Interior Horizontal R 2.5 X 4	(R2.5 @ Edge)	17 Btu/ft
Interior Horizontal R 5.0 X 2	(R2.5 @ Edge)	17 Btu/ft
Interior Horizontal R 5.0 X 4	(R2.5 @ Edge)	16 Btu/ft
Interior Horizontal R10.0 X 2	(R2.5 @ Edge)	17 Btu/ft
Interior Horizontal R10.0 X 4	(R2.5 @ Edge)	15 Btu/ft
Interior Vertical R 2.5	(R2.5 @ Edge)	19 Btu/ft
Interior Vertical R 5.0	(R2.5 @ Edge)	18 Btu/ft
Interior Vertical R10.0	(R2.5 @ Edge)	17 Btu/ft
Exterior Vertical R 2.5	Full height	18 Btu/ft
Exterior Vertical R 5.0	Full height	14 Btu/ft
Exterior Vertical R10.0	Full height	12 Btu/ft

Albany Design Heat Loss **Table 5.3**

Conclusion

Conclusion

The following conclusions may be drawn on the basis of this investigation:

1. The use of an uninsulated monolithic earth contact slab on grade floor assembly substantially increases the heating load of a residence in both Georgia locations.

2. The use of an uninsulated monolithic earth contact slab on grade floor assembly acts to reduce the cooling load of a residence in both Georgia locations.

3. Use of insulation relative to a monolithic slab on grade is primarily a heating consideration with a substantially smaller and location dependent effect on cooling load.

4. Energy flows associated with a monolithic earth contact slab on grade are subject to a thermal bridge from the interior to the above grade exposed edge at the perimeter which becomes the major determinant in effectiveness of insulation placement strategies.

5. Insulation strategies that do not address the nature of the thermal bridge are ineffective.

6. Increasing the R value for an interior insulation placement strategy is a non-linear relationship due to the nature of the thermal bridge and field temperature redistribution.

7. Appropriate use of insulation relative to a monolithic slab on grade can produce substantial energy savings on an annual basis equal to or greater than other common above grade energy efficiency techniques.

8. Appropriate use of insulation relative to a monolithic slab on grade is not

climate dependent for the conditions typical across the state of Georgia.

9. The use of ambient degree-day data as the decision basis for an energy code requirement fails to accurately describe the basic interaction of a slab assembly with the surrounding soil field.

10. Appropriate use of insulation relative to a monolithic slab on grade increases heating season slab surface temperatures which will reduce radiant energy transfer relative to occupancy increasing thermal comfort.

Placement of perimeter insulation at the exterior of the foundation wall in a vertical position from top of slab to top of footing is the most effective single technique of those considered. It should not interfere with construction of the slab assembly and may be placed at any time before backfill and rough grading occurs. The placement technique does require treatment of the exposed portion for appearance and should include horizontal insect shielding at the top of slab.

Slab assemblies without significant vertical dimension, thickened edges and grade beams would require a combination of exterior vertical and interior horizontal placement to achieve similar results.

Reccommendations

The authors reccommend a continuation of this study to consider the following issues:

1. Investigate energy movement in slab on grade construction consideing influence of another edge condition associated with a corner situation.

2. Investigate construction aspects of placement technique including moisture control, insect control, and exterior treatment.

3. Develop new guidelines stipulating the use of insulation relative to slab on grade construction for the Georgia Energy Code.

4. Effect field validation through instrumentation of an actual slab assembly with data collection, reduction, and analysis over a year period.

Appendix A
TNode Application

TNode

TNode is a finite element simulation developed to model thermal energy movement in a building context. It uses a forward differencing technique to determine the simultaneous solution of energy transfer functions in a three dimensional field using a Cholskey matrix manipulation technique.

Nodes are established representing discrete volumes of a unique mass. Physical properties of volume, density, specific heat, conductivity, nodal separation distance, and nodal area of interface are assigned to determine a representative nodal heat capacity and inter-nodal conductance relationships through the following relationships:

$$H = V * D * S$$

where

H = nodal heat capacity in Btu/cf-F
V = volume in cf
D = density in lb/cf
S = specific heat in Btu/lb-cf

$$C = (K1 * K2) / ((K1 * D2) + (K2 * D1))$$

where

C = inter-nodal conductance in Btu/sf-hr-F
K1 = conductivity of first node in Btu-ft/sf-hr-F
K2 = conductivity of second node in Btu-ft/sf-hr-F
D1 = distance from centroid of first node to area of interface between nodes
D2 = distance from centroid of second node to area of interface between nodes

The basic premise for heat transfer calculations between a node i and adjacent j nodes is stated as follows:

> The sum of conductances between all j nodes and node i multiplied by the difference in temperature between each respective node j and node i is equal to the capacitance of node i times the change in its

temperature over a given time interval.

The forward differencing methodology assumes that the temperature of all nodes remains constant during the time interval. This yields a basic relationship about which an energy balance may be established yielding a set of linear algaebraic equations equal in number to the total number of nodes. The Cholskey matrix technique solves the equations revealing a temperature at a future time equal to the present time plus the time increment.

With reasonably small time increments and node spacing the finite difference approximation approaches the exact partial differential equation solution. Inherent in the method are truncation errors determined by the numeric precision of the computational environment and system stability or convergence. Work by Razelos shows that maintenance of a dimensionles fourier modulus of 4 or greater ensures stability of the nodal system.

$$m = (dx^2) / \alpha\, dt$$

where

dt = Time increment in hours
dx = spacing in feet
α = thermal diffusivity in sf/hr
m = modulus

The basic thermal transfer relationships were modified to include influences of ambient conditions of temperature and solar radiation on any node in the field. Hourly ambient temperatures must be provided to the simulation from external data files prepared by the user. Unit hourly incident solar radiation must also be provided to the simulation from extrnal data files for each unique collecting surface orientation/tilt combination to be considered. In addition collecting surface area, absorptivity, and transmissivity must be identified. When a surface transmits radiation other nodes may gain transmitted energy of a percentage distribution basis.

Heating and/or cooling thermostats may be set on any node by hour for a typical day for each month. Following a simulation time step after nodal temperatures are calculated based on model influencce, node temperatures are reset to the scheduled thermostat value and the auxiliary energy required to affect the change is recorded.

Starting temperatures must be established for each node in the field. Each model generally requires a precursory simulation be preformed on the basis of an educated guess over an appropriate period of time to determine valid node starting temperatures.

TNode can record node temperatures, energy flows between any node, energy flows to and from ambient, and thermostat auxiliary energy for any node or combination at any interval that represents an even division of a day and is greater than or equal to the simulation time step. Data is date-time stamped and recorded on a storage device in a format that is compatible with importation into most popular spreadsheets.

Validation

The basic calculation kernal of the present TNode has been in use at Georgia Tech since 1980 when it was implemented as a part of a student thesis. Validation of the model has ocurred on several occasions during the life of the application the most notable being a comparison of TNode against the Krieth hypothetical model. A six inch thick concrete slab of one square foot at a constant temperature suddenly emersed in constant temperature body of air. Seven nodes are placed at one inch intervals from surface to surface with TNode yielding results within .01 degree Fahrenheit of the analytical solution over a twenty four hour period with a ten minute time step.

Appendix B

TNode Sample Input

TNode

Building Technology Group
College of Architecture
Georgia Tech
Atlanta, GA

Project

Name	T_NOINS
Number of nodes	84
Begin Simulation	Jan 01 Hour 00
End Simulation	Dec 31 Hour 23
Steps per hour	1

Notes

North solar radiation (soil abs.=0.3)

Air node at 300 * .075 lb/cf

January start temperatures from 60 day temp run

Heating Thermostat @ 68 F all months

Cooling thermostat @ 78 F all months

Internal gains from CALPAS/LoadCal

8" high exposed slab edge

Recording Setup

Begin recording	Jan 01 Hour 00
End recording	Dec 31 Hour 23
Number recordings per day	1

Record temperatures

None

Record flows

01 to 02	03 to 01	04 to 12
01 to 03	04 to 01	05 to 13
01 to 04	05 to 01	06 to 14
01 to 05	06 to 01	07 to 15
01 to 06	07 to 01	08 to 16
01 to 07	08 to 01	09 to 10
01 to 08	03 to 10	09 to 17
02 to 01	03 to 11	00 to 00

User Node Classifications

Class	Description followed by class node numbers
1	Horizontal concrete slab

2	3	4	5	6	7	8	9	0	0
0	0	0	0	0	0	0	0	0	0

Class	Description
2	Vertical concrete foundation wall

17	25	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Class	Description
3	Horizontal concrete footing

33	34	65	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Class	Description
4	Soil 0-4" below slab

10	11	12	13	14	15	16	0	0	0
0	0	0	0	0	0	0	0	0	0

Class	Description
5	Soil 4-12" below slab

18	19	20	21	22	23	24	0	0	0
0	0	0	0	0	0	0	0	0	0

Class	Description
6	Soil 12-20" below slab

26	27	28	29	30	31	32	0	0	0
0	0	0	0	0	0	0	0	0	0

Class	Description
7	Soil 20-40" below slab or footing

35	36	37	38	39	40	41	42	43	62
0	0	0	0	0	0	0	0	0	0

Class Description followed by class node numbers

8 Soil 40-64" below slab or footing

44	45	46	47	48	49	0	0	0	0
0	0	0	0	0	0	0	0	0	0

9 Soil at surface

78	79	80	81	82	83	84	0	0	0
0	0	0	0	0	0	0	0	0	0

10 Soil 0-8" below surface

71	72	73	74	75	76	77	0	0	0
0	0	0	0	0	0	0	0	0	0

11 Soil 8-16" below surface

63	64	65	66	67	68	69	70	0	0
0	0	0	0	0	0	0	0	0	0

12 Soil 16-36" below surface and slab

44	45	46	47	48	49	57	58	59	60
61	0	0	0	0	0	0	0	0	0

13 Soil 36-60" below surface and slab

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

14 Soil 5-10' below surface and slab

50	51	52	54	55	56	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Node Capacitance

Node	Capacitance	Volume	Density	Sp. Heat
1	720.1	133.36	22.500	0.24
2	6.78	0.22	140.000	0.22
3	6.78	0.22	140.000	0.22
4	13.55	0.44	140.000	0.22
5	20.64	0.67	140.000	0.22
6	30.80	1.00	140.000	0.22
7	40.96	1.33	140.000	0.22
8	51.44	1.67	140.000	0.22
9	6.78	0.22	140.000	0.22
10	2.78	0.11	110.000	0.23
11	2.78	0.11	110.000	0.23
12	11.13	0.44	110.000	0.23
13	16.95	0.67	110.000	0.23
14	25.30	1.00	110.000	0.23
15	33.65	1.33	110.000	0.23
16	42.25	1.67	110.000	0.23
17	13.55	0.44	140.000	0.22
18	5.57	0.22	110.000	0.23
19	5.57	0.22	110.000	0.23
20	22.52	0.89	110.000	0.23
21	33.65	1.33	110.000	0.23
22	50.60	2.00	110.000	0.23
23	67.55	2.67	110.000	0.23
24	84.25	3.33	110.000	0.23
25	13.55	0.44	140.000	0.22
26	5.57	0.22	110.000	0.23
27	5.57	0.22	110.000	0.23
28	22.52	0.89	110.000	0.23
29	33.65	1.33	110.000	0.23
30	50.60	2.00	110.000	0.23
31	67.55	2.67	110.000	0.23
32	84.25	3.33	110.000	0.23
33	13.55	0.44	140.000	0.22
34	13.55	0.44	140.000	0.22
35	22.52	0.89	110.000	0.23
36	33.65	1.33	110.000	0.23
37	16.95	0.67	110.000	0.23
38	16.95	0.67	110.000	0.23
39	33.65	1.33	110.000	0.23
40	50.60	2.00	110.000	0.23
41	126.50	5.00	110.000	0.23
42	168.75	6.67	110.000	0.23
43	210.75	8.33	110.000	0.23
44	33.65	1.33	110.000	0.23

Node Capacitance

Node	Capacitance	Volume	Density	Sp. Heat
45	101.20	4.00	110.000	0.23
46	101.20	4.00	110.000	0.23
47	151.80	6.00	110.000	0.23
48	202.40	8.00	110.000	0.23
49	253.00	10.00	110.000	0.23
50	84.25	3.33	110.000	0.23
51	506.00	20.00	110.000	0.23
52	1518.00	60.00	110.000	0.23
53	7000.51	276.70	110.000	0.23
54	506.00	20.00	110.000	0.23
55	885.50	35.00	110.000	0.23
56	1265.00	50.00	110.000	0.23
57	101.20	4.00	110.000	0.23
58	101.20	4.00	110.000	0.23
59	151.80	6.00	110.000	0.23
60	202.40	8.00	110.000	0.23
61	506.00	20.00	110.000	0.23
62	16.95	0.67	110.000	0.23
63	33.65	1.33	110.000	0.23
64	50.60	2.00	110.000	0.23
65	11.13	0.44	110.000	0.23
66	22.52	0.89	110.000	0.23
67	33.65	1.33	110.000	0.23
68	126.50	5.00	110.000	0.23
69	168.75	6.67	110.000	0.23
70	421.75	16.67	110.000	0.23
71	5.57	0.22	110.000	0.23
72	5.57	0.22	110.000	0.23
73	22.52	0.89	110.000	0.23
74	33.65	1.33	110.000	0.23
75	50.60	2.00	110.000	0.23
76	67.55	2.67	110.000	0.23
77	168.75	6.67	110.000	0.23
78	5.57	0.22	110.000	0.23
79	5.57	0.22	110.000	0.23
80	22.52	0.89	110.000	0.23
81	33.65	1.33	110.000	0.23
82	50.60	2.00	110.000	0.23
83	67.55	2.67	110.000	0.23
84	168.75	6.67	110.000	0.23

Node Conductance

Node Pairs	C * Area	K One	Dist One	K Two	Dist Two	Area
01 to 02	0.36	0.00	0.00	1.00	0.00	0.00
01 to 03	0.72	0.00	0.00	1.00	0.00	0.00
01 to 04	1.44	0.00	0.00	1.00	0.00	0.00
01 to 05	2.16	0.00	0.00	1.00	0.00	0.00
01 to 06	3.24	0.00	0.00	1.00	0.00	0.00
01 to 07	4.32	0.00	0.00	1.00	0.00	0.00
01 to 08	5.40	0.00	0.00	1.00	0.00	0.00
02 to 03	0.50	1.00	0.33	1.00	0.33	0.33
02 to 09	1.97	1.00	0.17	1.00	0.17	0.67
03 to 04	0.33	1.00	0.33	1.00	0.67	0.33
03 to 10	0.83	1.00	0.17	0.75	0.17	0.33
03 to 11	0.83	1.00	0.17	0.75	0.17	0.33
04 to 05	0.20	1.00	0.67	1.00	1.00	0.33
04 to 12	3.35	1.00	0.17	0.75	0.17	1.33
05 to 06	0.13	1.00	1.00	1.00	1.50	0.33
05 to 13	5.36	1.00	0.16	0.75	0.16	2.00
06 to 07	0.09	1.00	1.50	1.00	2.00	0.33
06 to 14	7.56	1.00	0.17	0.75	0.17	3.00
07 to 08	0.07	1.00	2.00	1.00	2.50	0.33
07 to 15	10.08	1.00	0.17	0.75	0.17	4.00
08 to 16	12.60	1.00	0.17	0.75	0.17	5.00
09 to 10	0.59	1.00	0.33	0.75	0.17	0.33
09 to 17	1.34	1.00	0.17	1.00	0.33	0.67
10 to 11	0.73	0.75	0.17	0.75	0.17	0.33
10 to 18	0.50	0.75	0.17	0.75	0.33	0.33
11 to 12	0.29	0.75	0.17	0.75	0.67	0.33
11 to 19	0.50	0.75	0.17	0.75	0.33	0.33
12 to 13	0.15	0.75	0.67	0.75	1.00	0.33
12 to 20	2.00	0.75	0.17	0.75	0.33	1.33
13 to 14	0.10	0.75	1.00	0.75	1.50	0.33
13 to 21	3.00	0.75	0.17	0.75	0.33	2.00
14 to 15	0.07	0.75	1.50	0.75	2.00	0.33
14 to 22	4.50	0.75	0.17	0.75	0.33	3.00
15 to 16	0.05	0.75	2.00	0.75	2.50	0.33
15 to 23	6.00	0.75	0.17	0.75	0.33	4.00
16 to 24	7.50	0.75	0.17	0.75	0.33	5.00
17 to 18	1.20	1.00	0.33	0.75	0.17	0.67
17 to 25	1.01	1.00	0.33	1.00	0.33	0.67
17 to 78	1.20	1.00	0.33	0.75	0.17	0.67
18 to 19	1.48	0.75	0.17	0.75	0.17	0.67
18 to 26	0.38	0.75	0.33	0.75	0.33	0.33
19 to 20	0.60	0.75	0.17	0.75	0.67	0.67
19 to 27	0.38	0.75	0.33	0.75	0.33	0.33
20 to 21	0.30	0.75	0.67	0.75	1.00	0.67

Node Conductance

Node Pairs	C * Area	K One	Dist One	K Two	Dist Two	Area
20 to 28	1.51	0.75	0.33	0.75	0.33	1.33
21 to 22	0.20	0.75	1.00	0.75	1.50	0.67
21 to 29	2.27	0.75	0.33	0.75	0.33	2.00
22 to 23	0.14	0.75	1.50	0.75	2.00	0.67
22 to 30	3.41	0.75	0.33	0.75	0.33	3.00
23 to 24	0.11	0.75	2.00	0.75	2.50	0.67
23 to 31	4.55	0.75	0.33	0.75	0.33	4.00
24 to 32	5.68	0.75	0.33	0.75	0.33	5.00
25 to 26	1.20	1.00	0.33	0.75	0.17	0.67
25 to 33	1.01	1.00	0.33	1.00	0.33	0.67
25 to 71	1.20	1.00	0.33	0.75	0.17	0.67
26 to 27	1.48	0.75	0.17	0.75	0.17	0.67
26 to 34	0.43	0.75	0.33	1.00	0.33	0.33
27 to 28	0.60	0.75	0.17	0.75	0.67	0.67
27 to 34	0.43	0.75	0.33	1.00	0.33	0.33
28 to 29	0.30	0.75	0.67	0.75	1.00	0.67
28 to 35	1.51	0.75	0.33	0.75	0.33	1.33
29 to 30	0.20	0.75	1.00	0.75	1.50	0.67
29 to 36	2.27	0.75	0.33	0.75	0.33	2.00
30 to 31	0.14	0.75	1.50	0.75	2.00	0.67
30 to 41	1.94	0.75	0.33	0.75	0.83	3.00
31 to 32	0.11	0.75	2.00	0.75	2.50	0.67
31 to 42	2.59	0.75	0.33	0.75	0.83	4.00
32 to 43	3.23	0.75	0.33	0.75	0.83	5.00
33 to 34	1.01	1.00	0.33	1.00	0.33	0.67
33 to 37	0.67	1.00	0.33	0.75	0.50	0.67
33 to 65	1.01	1.00	0.33	1.00	0.33	0.67
34 to 35	0.55	1.00	0.33	0.75	0.67	0.67
34 to 38	0.67	1.00	0.33	0.75	0.50	0.67
35 to 36	0.30	0.75	0.67	0.75	1.00	0.67
35 to 39	1.20	0.75	0.33	0.75	0.50	1.33
36 to 40	1.81	0.75	0.33	0.75	0.50	2.00
36 to 41	0.20	0.75	1.01	0.75	1.53	0.67
37 to 38	1.14	0.75	0.33	0.75	0.33	1.00
37 to 44	0.34	0.75	0.50	0.75	1.00	0.67
37 to 62	1.14	0.75	0.33	0.75	0.33	1.00
38 to 39	0.75	0.75	0.33	0.75	0.67	1.00
38 to 45	0.31	0.75	0.55	0.75	1.10	0.67
39 to 40	0.45	0.75	0.67	0.75	1.00	1.00
39 to 45	0.66	0.75	0.50	0.75	1.01	1.33
40 to 41	0.30	0.75	1.01	0.75	1.51	1.00
40 to 46	1.00	0.75	0.50	0.75	1.00	2.00
41 to 42	0.36	0.75	1.50	0.75	2.00	1.67
41 to 47	1.23	0.75	0.83	0.75	1.00	3.00

Node Conductance

Node Pairs	C * Area	K One	Dist One	K Two	Dist Two	Area
42 to 43	0.28	0.75	2.00	0.75	2.50	1.67
42 to 48	1.64	0.75	0.83	0.75	1.00	4.00
43 to 49	2.05	0.75	0.83	0.75	1.00	5.00
44 to 45	1.13	0.75	0.33	0.75	1.00	2.00
44 to 50	0.14	0.75	1.00	0.75	2.50	0.67
44 to 57	1.13	0.75	0.33	0.75	1.00	2.00
45 to 46	0.75	0.75	1.00	0.75	1.00	2.00
45 to 51	0.41	0.75	1.04	0.75	2.60	2.00
46 to 47	0.60	0.75	1.00	0.75	1.50	2.00
46 to 51	0.41	0.75	1.04	0.75	2.60	2.00
47 to 48	0.43	0.75	1.50	0.75	2.00	2.00
47 to 52	0.40	0.75	1.62	0.75	4.07	3.00
48 to 49	0.33	0.75	2.00	0.75	2.50	2.00
48 to 52	0.82	0.75	1.04	0.75	2.60	4.00
49 to 52	0.76	0.75	1.41	0.75	3.53	5.00
50 to 51	1.61	0.75	0.33	0.75	2.00	5.00
50 to 53	0.06	0.75	2.64	0.75	5.27	0.67
50 to 54	1.61	0.75	0.33	0.75	2.00	5.00
51 to 52	0.47	0.75	2.00	0.75	6.00	5.00
51 to 53	0.40	0.75	2.50	0.75	5.00	4.00
52 to 53	0.83	0.75	3.60	0.75	7.23	*.**
53 to 54	0.34	0.75	5.94	0.75	2.97	4.00
53 to 55	0.41	0.75	8.51	0.75	4.25	7.00
54 to 55	0.68	0.75	2.00	0.75	3.50	5.00
54 to 57	0.41	0.75	2.64	0.75	1.04	2.00
54 to 58	0.41	0.75	2.60	0.75	1.04	2.00
55 to 56	0.44	0.75	3.50	0.75	5.00	5.00
55 to 59	0.56	0.75	2.88	0.75	1.15	3.00
55 to 60	0.79	0.75	2.72	0.75	1.09	4.00
57 to 58	0.75	0.75	1.00	0.75	1.00	2.00
57 to 62	0.31	0.75	1.10	0.75	0.55	0.67
57 to 63	0.66	0.75	1.01	0.75	0.50	1.33
58 to 59	0.60	0.75	1.00	0.75	1.50	2.00
58 to 64	1.00	0.75	1.00	0.75	0.50	2.00
59 to 60	0.43	0.75	1.50	0.75	2.00	2.00
59 to 68	1.23	0.75	1.00	0.75	0.83	3.00
60 to 61	0.21	0.75	2.00	0.75	5.00	2.00
60 to 69	1.64	0.75	1.00	0.75	0.83	4.00
61 to 70	4.10	0.75	1.00	0.75	0.83	10.00
62 to 63	0.76	0.75	0.33	0.75	0.66	1.00
62 to 65	0.67	0.75	0.50	1.00	0.33	0.67
63 to 64	0.45	0.75	0.67	0.75	1.00	1.00
63 to 66	1.20	0.75	0.50	0.75	0.33	1.33
64 to 67	1.81	0.75	0.50	0.75	0.33	2.00

Node Conductance

Node Pairs	C * Area	K One	Dist One	K Two	Dist Two	Area
64 to 68	0.30	0.75	1.01	0.75	1.51	1.00
65 to 66	0.55	1.00	0.33	0.75	0.67	0.67
65 to 71	0.43	1.00	0.33	0.75	0.33	0.33
65 to 72	0.43	1.00	0.33	0.75	0.33	0.33
66 to 67	0.30	0.75	0.67	0.75	1.00	0.67
66 to 73	1.51	0.75	0.33	0.75	0.33	1.33
67 to 68	0.20	0.75	1.01	0.75	1.53	0.67
67 to 74	2.27	0.75	0.33	0.75	0.33	2.00
68 to 69	0.36	0.75	1.50	0.75	2.00	1.67
68 to 75	1.94	0.75	0.83	0.75	0.33	3.00
69 to 70	0.18	0.75	2.00	0.75	5.00	1.67
69 to 76	2.59	0.75	0.83	0.75	0.33	4.00
70 to 77	6.47	0.75	0.83	0.75	0.33	10.00
71 to 72	1.48	0.75	0.17	0.75	0.17	0.67
71 to 78	0.38	0.75	0.33	0.75	0.33	0.33
72 to 73	0.60	0.75	0.17	0.75	0.67	0.67
72 to 79	0.38	0.75	0.33	0.75	0.33	0.33
73 to 74	0.30	0.75	0.67	0.75	1.00	0.67
73 to 80	1.51	0.75	0.33	0.75	0.33	1.33
74 to 75	0.20	0.75	1.00	0.75	1.50	0.67
74 to 81	2.27	0.75	0.33	0.75	0.33	2.00
75 to 76	0.14	0.75	1.50	0.75	2.00	0.67
75 to 82	3.41	0.75	0.33	0.75	0.33	3.00
76 to 77	0.07	0.75	2.00	0.75	5.00	0.67
76 to 83	4.55	0.75	0.33	0.75	0.33	4.00
77 to 84	11.36	0.75	0.33	0.75	0.33	10.00
78 to 79	1.48	0.75	0.17	0.75	0.17	0.67
79 to 80	0.60	0.75	0.17	0.75	0.67	0.67
80 to 81	0.30	0.75	0.67	0.75	1.00	0.67
81 to 82	0.20	0.75	1.00	0.75	1.50	0.67
82 to 83	0.14	0.75	1.50	0.75	2.00	0.67
83 to 84	0.07	0.75	2.00	0.75	5.00	0.67

Node Initial Temperatures

Node	Temp	Node	Temp	Node	Temp
1	67.81	29	64.29	57	57.56
2	54.21	30	66.17	58	56.15
3	61.19	31	66.94	59	55.16
4	64.69	32	67.19	60	55.03
5	66.47	33	56.38	61	56.87
6	67.27	34	57.97	62	56.24
7	67.55	35	60.69	63	55.03
8	67.64	36	63.69	64	53.67
9	53.48	37	57.41	65	55.16
10	58.61	38	58.73	66	53.55
11	60.21	39	60.60	67	52.37
12	63.61	40	63.23	68	52.40
13	65.97	41	65.49	69	52.25
14	67.03	42	66.49	70	53.08
15	67.43	43	66.84	71	54.52
16	67.55	44	59.07	72	53.92
17	55.03	45	60.71	73	52.67
18	57.33	46	62.86	74	51.82
19	58.82	47	64.94	75	51.49
20	62.16	48	65.93	76	51.42
21	65.13	49	66.33	77	51.75
22	66.63	50	61.65	78	51.58
23	67.21	51	62.67	79	50.80
24	67.39	52	65.10	80	50.30
25	55.69	53	64.24	81	50.07
26	57.17	54	60.69	82	49.99
27	58.26	55	59.92	83	49.97
28	61.15	56	64.75	84	50.04

Node Conductance to Ambient

Node	Cond	Node	Cond	Node	Cond
1	0.00	29	0.00	57	0.00
2	1.32	30	0.00	58	0.00
3	0.00	31	0.00	59	0.00
4	0.00	32	0.00	60	0.00
5	0.00	33	0.00	61	0.00
6	0.00	34	0.00	62	0.00
7	0.00	35	0.00	63	0.00
8	0.00	36	0.00	64	0.00
9	1.32	37	0.00	65	0.00
10	0.00	38	0.00	66	0.00
11	0.00	39	0.00	67	0.00
12	0.00	40	0.00	68	0.00
13	0.00	41	0.00	69	0.00
14	0.00	42	0.00	70	0.00
15	0.00	43	0.00	71	0.00
16	0.00	44	0.00	72	0.00
17	0.00	45	0.00	73	0.00
18	0.00	46	0.00	74	0.00
19	0.00	47	0.00	75	0.00
20	0.00	48	0.00	76	0.00
21	0.00	49	0.00	77	0.00
22	0.00	50	0.00	78	1.32
23	0.00	51	0.00	79	1.32
24	0.00	52	0.00	80	5.32
25	0.00	53	0.00	81	8.00
26	0.00	54	0.00	82	12.00
27	0.00	55	0.00	83	16.00
28	0.00	56	0.00	84	40.00

Node 1 January Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-148.00	6	-154.00	12	-38.00	18	-67.00
1	-154.00	7	-142.00	13	-34.00	19	-83.00
2	-158.00	8	-100.00	14	-34.00	20	-96.00
3	-160.00	9	-68.00	15	-36.00	21	-108.00
4	-162.00	10	-54.00	16	-42.00	22	-123.00
5	-160.00	11	-44.00	17	-53.00	23	-137.00

Node 1 February Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-120.00	6	-146.00	12	-18.00	18	-38.00
1	-132.00	7	-134.00	13	-14.00	19	-54.00
2	-140.00	8	-98.00	14	-14.00	20	-68.00
3	-144.00	9	-62.00	15	-16.00	21	-79.00
4	-148.00	10	-36.00	16	-18.00	22	-94.00
5	-148.00	11	-24.00	17	-26.00	23	-111.00

Node 1 March Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-81.00	6	-102.00	12	14.00	18	-2.00
1	-88.00	7	-76.00	13	20.00	19	-14.00
2	-94.00	8	-31.00	14	24.00	20	-26.00
3	-100.00	9	-12.00	15	26.00	21	-36.00
4	-103.00	10	0.00	16	24.00	22	-48.00
5	-106.00	11	6.00	17	12.00	23	-62.00

Node 1 April Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-19.00	6	-30.00	12	64.00	18	31.00
1	-25.00	7	-12.00	13	78.00	19	10.00
2	-30.00	8	4.00	14	84.00	20	4.00
3	-33.00	9	19.00	15	86.00	21	0.00
4	-35.00	10	36.00	16	82.00	22	-6.00
5	-34.00	11	50.00	17	66.00	23	-10.00

Node 1 May Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-4.00	6	-11.00	12	104.00	18	53.00
1	-10.00	7	2.00	13	112.00	19	21.00
2	-14.00	8	14.00	14	116.00	20	9.00
3	-18.00	9	38.00	15	114.00	21	2.00
4	-20.00	10	66.00	16	110.00	22	-2.00
5	-18.00	11	92.00	17	88.00	23	-4.00

Node 1 June Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-2.00	6	3.00	12	130.00	18	68.00
1	-4.00	7	15.00	13	132.00	19	34.00
2	-6.00	8	37.00	14	134.00	20	21.00
3	-8.00	9	71.00	15	132.00	21	12.00
4	-6.00	10	108.00	16	126.00	22	6.00
5	-4.00	11	122.00	17	105.00	23	0.00

Node 1 July Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	4.00	6	12.00	12	143.00	18	85.00
1	3.00	7	27.00	13	146.00	19	42.00
2	1.00	8	61.00	14	146.00	20	28.00
3	0.00	9	102.00	15	142.00	21	18.00
4	0.00	10	130.00	16	136.00	22	10.00
5	5.00	11	138.00	17	120.00	23	4.00

Node 1 August Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-1.00	6	4.00	12	148.00	18	66.00
1	-4.00	7	16.00	13	150.00	19	38.00
2	-6.00	8	46.00	14	152.00	20	26.00
3	-6.00	9	96.00	15	150.00	21	18.00
4	-4.00	10	130.00	16	142.00	22	10.00
5	-1.00	11	142.00	17	111.00	23	2.00

Node 1 September Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-5.00	6	-4.00	12	116.00	18	40.00
1	-7.00	7	4.00	13	118.00	19	23.00
2	-9.00	8	18.00	14	116.00	20	13.00
3	-9.00	9	43.00	15	110.00	21	7.00
4	-10.00	10	82.00	16	98.00	22	2.00
5	-7.00	11	102.00	17	72.00	23	-3.00

Node 1 October Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-21.00	6	-48.00	12	64.00	18	4.00
1	-27.00	7	-24.00	13	76.00	19	-2.00
2	-35.00	8	-4.00	14	82.00	20	-6.00
3	-40.00	9	11.00	15	72.00	21	-10.00
4	-46.00	10	28.00	16	52.00	22	-14.00
5	-50.00	11	44.00	17	18.00	23	-18.00

Node 1 November Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-79.00	6	-102.00	12	18.00	18	-14.00
1	-89.00	7	-86.00	13	24.00	19	-25.00
2	-95.00	8	-40.00	14	28.00	20	-35.00
3	-100.00	9	-14.00	15	22.00	21	-46.00
4	-103.00	10	-1.00	16	10.00	22	-60.00
5	-104.00	11	8.00	17	-2.00	23	-74.00

Node 1 December Internal Gain

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	-128.00	6	-142.00	12	-22.00	18	-52.00
1	-133.00	7	-130.00	13	-20.00	19	-64.00
2	-137.00	8	-80.00	14	-18.00	20	-79.00
3	-142.00	9	-49.00	15	-22.00	21	-90.00
4	-145.00	10	-36.00	16	-29.00	22	-102.00
5	-145.00	11	-28.00	17	-40.00	23	-118.00

Node 02 Radiation

		Distribution Node	Distribution Percent	Distribution Node	Distribution Percent
		0	0.00	0	0.00
Area	0.3	0	0.00	0	0.00
Abs.	0.75	0	0.00	0	0.00
Trn.	0.00	0	0.00	0	0.00

Node 09 Radiation

		Distribution Node	Distribution Percent	Distribution Node	Distribution Percent
		0	0.00	0	0.00
Area	0.3	0	0.00	0	0.00
Abs.	0.75	0	0.00	0	0.00
Trn.	0.00	0	0.00	0	0.00

Node 78 Radiation

		Distribution Node	Distribution Percent	Distribution Node	Distribution Percent
		0	0.00	0	0.00
Area	0.3	0	0.00	0	0.00
Abs.	0.30	0	0.00	0	0.00
Trn.	0.00	0	0.00	0	0.00

Node 79 Radiation

		Distribution Node	Distribution Percent	Distribution Node	Distribution Percent
		0	0.00	0	0.00
Area	0.3	0	0.00	0	0.00
Abs.	0.30	0	0.00	0	0.00
Trn.	0.00	0	0.00	0	0.00

Node 80 Radiation

		Distribution Node	Distribution Percent	Distribution Node	Distribution Percent
		0	0.00	0	0.00
Area	1.3	0	0.00	0	0.00
Abs.	0.30	0	0.00	0	0.00
Trn.	0.00	0	0.00	0	0.00

Node 81 Radiation

		Distribution Node	Percent	Distribution Node	Percent
		0	0.00	0	0.00
Area	2.0	0	0.00	0	0.00
Abs.	0.30	0	0.00	0	0.00
Trn.	0.00	0	0.00	0	0.00

Node 82 Radiation

		Distribution Node	Percent	Distribution Node	Percent
		0	0.00	0	0.00
Area	3.0	0	0.00	0	0.00
Abs.	0.30	0	0.00	0	0.00
Trn.	0.00	0	0.00	0	0.00

Node 83 Radiation

		Distribution Node	Percent	Distribution Node	Percent
		0	0.00	0	0.00
Area	4.0	0	0.00	0	0.00
Abs.	0.30	0	0.00	0	0.00
Trn.	0.00	0	0.00	0	0.00

Node 84 Radiation

		Distribution Node	Percent	Distribution Node	Percent
		0	0.00	0	0.00
Area	10.0	0	0.00	0	0.00
Abs.	0.30	0	0.00	0	0.00
Trn.	0.00	0	0.00	0	0.00

Node 1 January Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 February Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 March Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 April Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 May Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 June Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 July Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 August Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 September Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 October Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 November Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 December Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.00	6	68.00	12	68.00	18	68.00
1	68.00	7	68.00	13	68.00	19	68.00
2	68.00	8	68.00	14	68.00	20	68.00
3	68.00	9	68.00	15	68.00	21	68.00
4	68.00	10	68.00	16	68.00	22	68.00
5	68.00	11	68.00	17	68.00	23	68.00

Node 1 January Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 February Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 March Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 April Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 May Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 June Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 July Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 August Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 September Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 October Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 November Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 1 December Cooling Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	78.00	6	78.00	12	78.00	18	78.00
1	78.00	7	78.00	13	78.00	19	78.00
2	78.00	8	78.00	14	78.00	20	78.00
3	78.00	9	78.00	15	78.00	21	78.00
4	78.00	10	78.00	16	78.00	22	78.00
5	78.00	11	78.00	17	78.00	23	78.00

Node 53 January Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	62.10	6	62.10	12	62.10	18	62.10
1	62.10	7	62.10	13	62.10	19	62.10
2	62.10	8	62.10	14	62.10	20	62.10
3	62.10	9	62.10	15	62.10	21	62.10
4	62.10	10	62.10	16	62.10	22	62.10
5	62.10	11	62.10	17	62.10	23	62.10

Node 53 February Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	60.00	6	60.00	12	60.00	18	60.00
1	60.00	7	60.00	13	60.00	19	60.00
2	60.00	8	60.00	14	60.00	20	60.00
3	60.00	9	60.00	15	60.00	21	60.00
4	60.00	10	60.00	16	60.00	22	60.00
5	60.00	11	60.00	17	60.00	23	60.00

Node 53 March Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	58.10	6	58.10	12	58.10	18	58.10
1	58.10	7	58.10	13	58.10	19	58.10
2	58.10	8	58.10	14	58.10	20	58.10
3	58.10	9	58.10	15	58.10	21	58.10
4	58.10	10	58.10	16	58.10	22	58.10
5	58.10	11	58.10	17	58.10	23	58.10

Node 53 April Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	56.80	6	56.80	12	56.80	18	56.80
1	56.80	7	56.80	13	56.80	19	56.80
2	56.80	8	56.80	14	56.80	20	56.80
3	56.80	9	56.80	15	56.80	21	56.80
4	56.80	10	56.80	16	56.80	22	56.80
5	56.80	11	56.80	17	56.80	23	56.80

Node 53 May Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	56.50	6	56.50	12	56.50	18	56.50
1	56.50	7	56.50	13	56.50	19	56.50
2	56.50	8	56.50	14	56.50	20	56.50
3	56.50	9	56.50	15	56.50	21	56.50
4	56.50	10	56.50	16	56.50	22	56.50
5	56.50	11	56.50	17	56.50	23	56.50

Node 53 June Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	57.30	6	57.30	12	57.30	18	57.30
1	57.30	7	57.30	13	57.30	19	57.30
2	57.30	8	57.30	14	57.30	20	57.30
3	57.30	9	57.30	15	57.30	21	57.30
4	57.30	10	57.30	16	57.30	22	57.30
5	57.30	11	57.30	17	57.30	23	57.30

Node 53 July Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	58.90	6	58.90	12	58.90	18	58.90
1	58.90	7	58.90	13	58.90	19	58.90
2	58.90	8	58.90	14	58.90	20	58.90
3	58.90	9	58.90	15	58.90	21	58.90
4	58.90	10	58.90	16	58.90	22	58.90
5	58.90	11	58.90	17	58.90	23	58.90

Node 53 August Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	61.00	6	61.00	12	61.00	18	61.00
1	61.00	7	61.00	13	61.00	19	61.00
2	61.00	8	61.00	14	61.00	20	61.00
3	61.00	9	61.00	15	61.00	21	61.00
4	61.00	10	61.00	16	61.00	22	61.00
5	61.00	11	61.00	17	61.00	23	61.00

Node 53 September Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	62.90	6	62.90	12	62.90	18	62.90
1	62.90	7	62.90	13	62.90	19	62.90
2	62.90	8	62.90	14	62.90	20	62.90
3	62.90	9	62.90	15	62.90	21	62.90
4	62.90	10	62.90	16	62.90	22	62.90
5	62.90	11	62.90	17	62.90	23	62.90

Node 53 October Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	64.20	6	64.20	12	64.20	18	64.20
1	64.20	7	64.20	13	64.20	19	64.20
2	64.20	8	64.20	14	64.20	20	64.20
3	64.20	9	64.20	15	64.20	21	64.20
4	64.20	10	64.20	16	64.20	22	64.20
5	64.20	11	64.20	17	64.20	23	64.20

Node 53 November Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	64.50	6	64.50	12	64.50	18	64.50
1	64.50	7	64.50	13	64.50	19	64.50
2	64.50	8	64.50	14	64.50	20	64.50
3	64.50	9	64.50	15	64.50	21	64.50
4	64.50	10	64.50	16	64.50	22	64.50
5	64.50	11	64.50	17	64.50	23	64.50

Node 53 December Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	63.70	6	63.70	12	63.70	18	63.70
1	63.70	7	63.70	13	63.70	19	63.70
2	63.70	8	63.70	14	63.70	20	63.70
3	63.70	9	63.70	15	63.70	21	63.70
4	63.70	10	63.70	16	63.70	22	63.70
5	63.70	11	63.70	17	63.70	23	63.70

Node 56 January Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	56.80	6	56.80	12	56.80	18	56.80
1	56.80	7	56.80	13	56.80	19	56.80
2	56.80	8	56.80	14	56.80	20	56.80
3	56.80	9	56.80	15	56.80	21	56.80
4	56.80	10	56.80	16	56.80	22	56.80
5	56.80	11	56.80	17	56.80	23	56.80

Node 56 February Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	53.10	6	53.10	12	53.10	18	53.10
1	53.10	7	53.10	13	53.10	19	53.10
2	53.10	8	53.10	14	53.10	20	53.10
3	53.10	9	53.10	15	53.10	21	53.10
4	53.10	10	53.10	16	53.10	22	53.10
5	53.10	11	53.10	17	53.10	23	53.10

Node 56 March Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	51.40	6	51.40	12	51.40	18	51.40
1	51.40	7	51.40	13	51.40	19	51.40
2	51.40	8	51.40	14	51.40	20	51.40
3	51.40	9	51.40	15	51.40	21	51.40
4	51.40	10	51.40	16	51.40	22	51.40
5	51.40	11	51.40	17	51.40	23	51.40

Node 56 April Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	52.10	6	52.10	12	52.10	18	52.10
1	52.10	7	52.10	13	52.10	19	52.10
2	52.10	8	52.10	14	52.10	20	52.10
3	52.10	9	52.10	15	52.10	21	52.10
4	52.10	10	52.10	16	52.10	22	52.10
5	52.10	11	52.10	17	52.10	23	52.10

Node 56 May Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	55.10	6	55.10	12	55.10	18	55.10
1	55.10	7	55.10	13	55.10	19	55.10
2	55.10	8	55.10	14	55.10	20	55.10
3	55.10	9	55.10	15	55.10	21	55.10
4	55.10	10	55.10	16	55.10	22	55.10
5	55.10	11	55.10	17	55.10	23	55.10

Node 56 June Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	59.50	6	59.50	12	59.50	18	59.50
1	59.50	7	59.50	13	59.50	19	59.50
2	59.50	8	59.50	14	59.50	20	59.50
3	59.50	9	59.50	15	59.50	21	59.50
4	59.50	10	59.50	16	59.50	22	59.50
5	59.50	11	59.50	17	59.50	23	59.50

Node 56 July Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	64.30	6	64.30	12	64.30	18	64.30
1	64.30	7	64.30	13	64.30	19	64.30
2	64.30	8	64.30	14	64.30	20	64.30
3	64.30	9	64.30	15	64.30	21	64.30
4	64.30	10	64.30	16	64.30	22	64.30
5	64.30	11	64.30	17	64.30	23	64.30

Node 56 August Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	67.90	6	67.90	12	67.90	18	67.90
1	67.90	7	67.90	13	67.90	19	67.90
2	67.90	8	67.90	14	67.90	20	67.90
3	67.90	9	67.90	15	67.90	21	67.90
4	67.90	10	67.90	16	67.90	22	67.90
5	67.90	11	67.90	17	67.90	23	67.90

Node 56 September Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	69.60	6	69.60	12	69.60	18	69.60
1	69.60	7	69.60	13	69.60	19	69.60
2	69.60	8	69.60	14	69.60	20	69.60
3	69.60	9	69.60	15	69.60	21	69.60
4	69.60	10	69.60	16	69.60	22	69.60
5	69.60	11	69.60	17	69.60	23	69.60

Node 56 October Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	68.90	6	68.90	12	68.90	18	68.90
1	68.90	7	68.90	13	68.90	19	68.90
2	68.90	8	68.90	14	68.90	20	68.90
3	68.90	9	68.90	15	68.90	21	68.90
4	68.90	10	68.90	16	68.90	22	68.90
5	68.90	11	68.90	17	68.90	23	68.90

Node 56 November Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	65.90	6	65.90	12	65.90	18	65.90
1	65.90	7	65.90	13	65.90	19	65.90
2	65.90	8	65.90	14	65.90	20	65.90
3	65.90	9	65.90	15	65.90	21	65.90
4	65.90	10	65.90	16	65.90	22	65.90
5	65.90	11	65.90	17	65.90	23	65.90

Node 56 December Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	61.40	6	61.40	12	61.40	18	61.40
1	61.40	7	61.40	13	61.40	19	61.40
2	61.40	8	61.40	14	61.40	20	61.40
3	61.40	9	61.40	15	61.40	21	61.40
4	61.40	10	61.40	16	61.40	22	61.40
5	61.40	11	61.40	17	61.40	23	61.40

Node 61 January Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	50.80	6	50.80	12	50.80	18	50.80
1	50.80	7	50.80	13	50.80	19	50.80
2	50.80	8	50.80	14	50.80	20	50.80
3	50.80	9	50.80	15	50.80	21	50.80
4	50.80	10	50.80	16	50.80	22	50.80
5	50.80	11	50.80	17	50.80	23	50.80

Node 61 February Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	47.40	6	47.40	12	47.40	18	47.40
1	47.40	7	47.40	13	47.40	19	47.40
2	47.40	8	47.40	14	47.40	20	47.40
3	47.40	9	47.40	15	47.40	21	47.40
4	47.40	10	47.40	16	47.40	22	47.40
5	47.40	11	47.40	17	47.40	23	47.40

Node 61 March Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	47.50	6	47.50	12	47.50	18	47.50
1	47.50	7	47.50	13	47.50	19	47.50
2	47.50	8	47.50	14	47.50	20	47.50
3	47.50	9	47.50	15	47.50	21	47.50
4	47.50	10	47.50	16	47.50	22	47.50
5	47.50	11	47.50	17	47.50	23	47.50

Node 61 April Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	51.00	6	51.00	12	51.00	18	51.00
1	51.00	7	51.00	13	51.00	19	51.00
2	51.00	8	51.00	14	51.00	20	51.00
3	51.00	9	51.00	15	51.00	21	51.00
4	51.00	10	51.00	16	51.00	22	51.00
5	51.00	11	51.00	17	51.00	23	51.00

Node 61 May Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	57.10	6	57.10	12	57.10	18	57.10
1	57.10	7	57.10	13	57.10	19	57.10
2	57.10	8	57.10	14	57.10	20	57.10
3	57.10	9	57.10	15	57.10	21	57.10
4	57.10	10	57.10	16	57.10	22	57.10
5	57.10	11	57.10	17	57.10	23	57.10

Node 61 June Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	64.10	6	64.10	12	64.10	18	64.10
1	64.10	7	64.10	13	64.10	19	64.10
2	64.10	8	64.10	14	64.10	20	64.10
3	64.10	9	64.10	15	64.10	21	64.10
4	64.10	10	64.10	16	64.10	22	64.10
5	64.10	11	64.10	17	64.10	23	64.10

Node 61 July Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	70.20	6	70.20	12	70.20	18	70.20
1	70.20	7	70.20	13	70.20	19	70.20
2	70.20	8	70.20	14	70.20	20	70.20
3	70.20	9	70.20	15	70.20	21	70.20
4	70.20	10	70.20	16	70.20	22	70.20
5	70.20	11	70.20	17	70.20	23	70.20

Node 61 August Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	73.60	6	73.60	12	73.60	18	73.60
1	73.60	7	73.60	13	73.60	19	73.60
2	73.60	8	73.60	14	73.60	20	73.60
3	73.60	9	73.60	15	73.60	21	73.60
4	73.60	10	73.60	16	73.60	22	73.60
5	73.60	11	73.60	17	73.60	23	73.60

Node 61 September Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	73.50	6	73.50	12	73.50	18	73.50
1	73.50	7	73.50	13	73.50	19	73.50
2	73.50	8	73.50	14	73.50	20	73.50
3	73.50	9	73.50	15	73.50	21	73.50
4	73.50	10	73.50	16	73.50	22	73.50
5	73.50	11	73.50	17	73.50	23	73.50

Node 61 October Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	70.00	6	70.00	12	70.00	18	70.00
1	70.00	7	70.00	13	70.00	19	70.00
2	70.00	8	70.00	14	70.00	20	70.00
3	70.00	9	70.00	15	70.00	21	70.00
4	70.00	10	70.00	16	70.00	22	70.00
5	70.00	11	70.00	17	70.00	23	70.00

Node 61 November Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	63.90	6	63.90	12	63.90	18	63.90
1	63.90	7	63.90	13	63.90	19	63.90
2	63.90	8	63.90	14	63.90	20	63.90
3	63.90	9	63.90	15	63.90	21	63.90
4	63.90	10	63.90	16	63.90	22	63.90
5	63.90	11	63.90	17	63.90	23	63.90

Node 61 December Heating Thermostat

Hour	Temp	Hour	Temp	Hour	Temp	Hour	Temp
0	56.90	6	56.90	12	56.90	18	56.90
1	56.90	7	56.90	13	56.90	19	56.90
2	56.90	8	56.90	14	56.90	20	56.90
3	56.90	9	56.90	15	56.90	21	56.90
4	56.90	10	56.90	16	56.90	22	56.90
5	56.90	11	56.90	17	56.90	23	56.90